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SOME RECENT EXPERIMENTS ON THE USE OF HIGH EXPLOSIVES FOR WAR PURPOSES.

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Since the processes have been perfected by which nitroglycerine and gun-cotton have been rendered comparatively safe during handling and storage, active efforts have been made to devise means for employing them as offensive and defensive agents. Heretofore these efforts have been confined to the use of these explosives in torpedoes and submarine mines, but while these have proved in some measure efficient, yet they have been found to be costly and difficult of application, especially when the enemy was in motion, while the apparatus could be used but once, since it was destroyed by its own explosion. Hence, attention is now directed towards the invention of methods which will combine accuracy and readiness of application to a desired point while admitting of rapid and repeated use. As gun-powder has been successfully used in shells, this method of projecting the high explosives has naturally suggested itself; but as these bodies have been found to be liable to undergo an explosive reaction if, when confined, they are exposed to a violent shock or to the influence of an explosive wave, and as the pressure exerted by the powder-gas, in the chamber of a gun, becomes very great before the projectile is moved from its seat, it has been generally feared that a shell charged with a high explosive would be exploded before it left the gun.

For this reason other means for propelling the projectile have been sought, and as it has been shown by the Perkins steam gun and the common air gun that the expansive force of high pressure steam, or of compressed gases, possesses for this purpose a considerable degree of efficiency, while at the same time the pressure can be so regulated that the projectile can be started without being subjected to any considerable initial shock, this form of gun has been recently adopted for experimental purposes. The velocity is attained by lengthening the gun so that the projectile is exposed for some time to the action of the expanding gases.

In Fig. 1, * the air gun recently under trial at Fort Lafayette, New York Harbor, is represented. It consists of a seamless brass tube forty feet long and one quarter inch in thickness, mounted upon a light steel girder. This is trunnioned and pivoted on to a cast iron base, thus enabling it to be swung in any desired position. To assist in this operation guys are placed on either side of the base and their length can be changed by turning the hand wheels. Compressed air is introduced to the gun from below and

* We are indebted to the *Scientific American* of April 8, 1884, for Figs. 1 and 2.

passes up through the center of the base to a pipe connecting with one of the trunnions, which is hollow. The air is thence introduced into the pipe on the side of the gun which leads to the valve. This valve is a continuation of the breech of the gun with which it is connected by a pipe leading upward. The valve is automatic in its action, and so regulates the supply of air that the pressure increases until the projectile leaves the gun, when the value closes.

The peculiar projectile used is shown in Fig. 2. It consists of a thin brass tube in which the dynamite charge is placed, an airspace is left at the rear to act as a cushion and then a wooden sabot is inserted. This sabot flares out until its diameter equals the internal diameter of the gun. The forward end of the brass tube is pointed with some soft material and the firing pin with its detonator is embedded in this, so that it cannot be fired except upon impact. The projectile is so constructed that its center of gravity is some distance forward of its center of figure. Hence a side wind would tend to turn its head into the wind and keep it

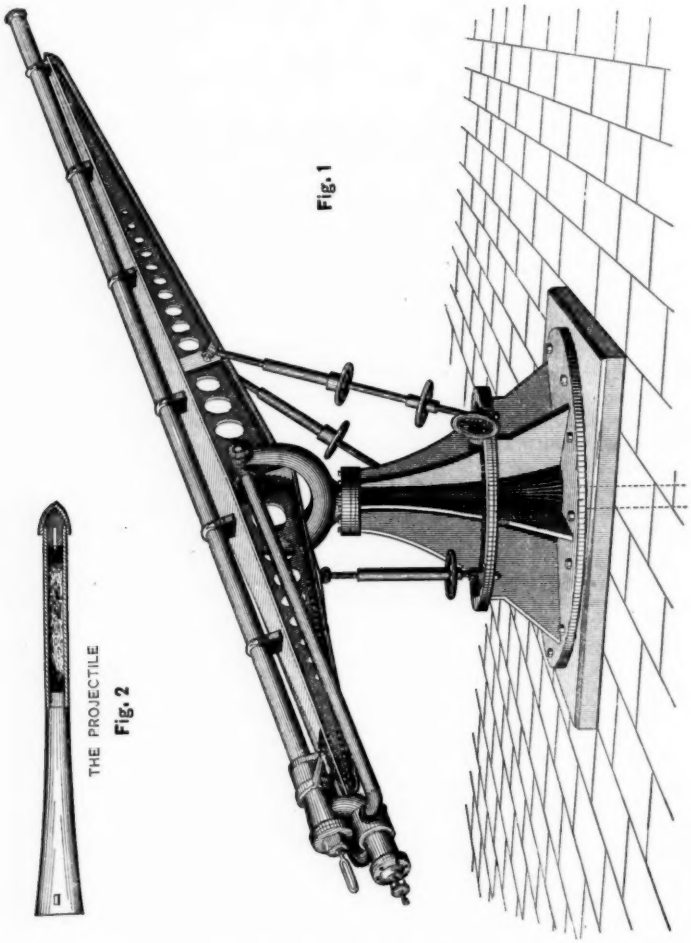


Fig. 1

THE PROJECTILE

Fig. 2

in the line of its trajectory. The gun is loaded by inserting the projectile in the breech and closing the gas check. The lever is then moved which opens the valve, admits the compressed air and discharges the gun.

The first gun tested by Lt. Zalinski was two inches in diameter, and with this a range of 1¼ mile was attained when using a pressure of 420 pounds to the sq. inch. The four-inch gun is made to withstand a pressure of 2000 pounds, but as thus far reported the pressure used but slightly exceeded 500 pounds. With a projectile weighing 24 pounds and a pressure of 500 pounds, a range of 2100 yards was attained when the elevation was 22 degrees. Numerous experiments have been made with projectiles containing dynamite, in some instances 15 pounds being used for one charge, and they have been fired without any premature explosions. The gun, however, yet appears to lack in accuracy of fire. This can probably be corrected after further experimentation, and the progress thus far made has shown that a gun can be cheaply and quickly constructed which will safely and rapidly throw considerable masses of the high explosives to a distance of over 1¼ miles, where they will be discharged on impact. These guns are also so light that they can easily be used on small launches, and the absence of all report and of a flash of light during the discharge, commends them for night attacks. It is proposed now to construct an eight-inch gun to carry from 100 to 125 pounds of explosive gelatine.

In determining the efficiency of these projectiles against an armor clad vessel, we may assume that one of four effects may be produced, depending on the resistance of the armor to penetration and on the material, thickness of wall, profile, weight and velocity of the projectile.

(1). The projectile may either penetrate the armor partially and explode in place, or pierce it completely and burst inside of the ship. This is the condition of greatest efficiency.

(2). It may explode immediately upon impact and before breaking up. Then the explosive will exert the energy which it develops through explosion in a resisting receptacle.

(3). It may rebound before exploding. Then the effect will be reduced by the interposed cushion of air.

(4). It may break up on impact before the explosion takes place. Then the energy of the explosive will be simply that which it develops when exploded unconfined.

The resistance of an armor to penetration depends upon its hardness, its tensile strength (that due to bolting as well as that inherent in the metal itself) and its inertia. The latter is augmented by the thickness and weight of the armor, and by the rigid system of bracing which now obtains in practice. How great this resistance is can best be illustrated by an example. While, from the fact that very rapid progress is being made in the improvement of armor plates, we may not have chosen the best example, let us take the steel plates designed for the *Furieux*. One of these, weighing 23 tons, 9 cwt, and averaging over 17 inches in thickness, was tested at Gâvre, July 13, 1883. Three shots were fired against this plate from a 12.6 inch rifle using chilled iron projectiles, weighing 759 pounds each. The first and second shot struck with a velocity of 1403 feet each. The third struck with a velocity of 1438 feet. The projectiles were all broken up, all of the twenty bolts through the plate remained intact, and no portion of the plate fell from the backing, although it was somewhat indented and cracked.

Although we are not yet informed concerning the air gun projectile, except for the weight given above and the pressure of the air also cited, yet when we remember that in the Gâvre experiments the pressure of the powder gas probably approached 40,000 lbs. to the square inch, it is not unfair to infer that with a pressure of 500 lbs. to the square inch a projectile will possess little or no penetrative power against the *Furieux* plates at a distance of 1¼ mile. Whether then the projectile would explode on impact or after rebounding, or whether it would break up before exploding, is a matter for speculation and conjecture. If the last condition prevails, then we can judge from some experiments recently made by Lieut.-Commander Folger, at the Naval Experimental Battery, under the direction of the Naval Bureau of Ordnance, what the destructive effect would probably be.

The target used in these experiments

is shown in Fig. 3. It consisted of eleven slightly convex iron plates, each one inch in thickness, which had been perforated with bolt holes. They were such plates as were used during the war for covering the turrets of the original monitors, and the bolt holes were made before the delivery of the plates. The plates were fastened to the twenty-inch thick oak backing by fourteen, tapering, 1½ inch iron bolts, which were flush on the surface of the target and passed entirely through the backing. These bolts are indicated in the figures by numbers. Before this target was constructed, 265 pounds of dynamite in ten successive charges, varying from five to seventy-five pounds, were exploded against plates fastened to this same structure without materially damaging it.

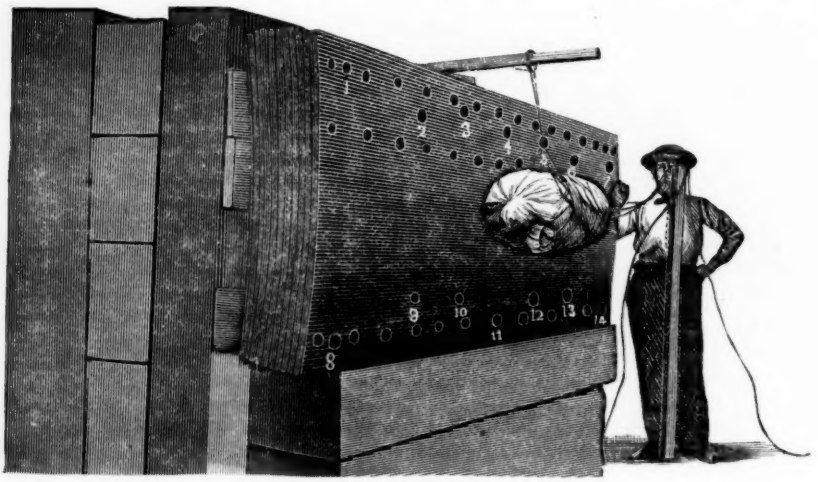


FIG. 3.

The No. 1 kisselguhr dynamite used was made at Newport, and was in excellent condition. The charge was placed in a woolen cartridge bag, a netting lashed about it and then the whole suspended from the wooden cross-piece which projected from above the target, as shown in Fig. 3. The cord suspending the charge was carried over and behind the top of the plates so as to bring the charge in contact with the face of the plates, and, as an additional precaution, the charge was jammed close against the target by pressing on it. A hole, about three inches deep, was made in the side of the charge farthest from the target, and two detonators, arranged in series, and containing together 85 grains of mercuric fulminate, were imbedded in it.

In the first experiment 100 pounds of dynamite were exploded as described. The result was the indentation of the plate to the depth of two inches at the center, and extending over a circular area of about two feet in diameter. The outer plate was sprung from the bolts at each end. The outer pair of plates separated about a quarter of an inch. In general, however, a good contact remained for all the plates. The backing and bracing were practically uninjured. An old crack in the middle upright, due to checking, had widened slightly. The whole structure had sprung back two inches, but had recovered itself in the marshy ground in which it was imbedded.

In the next experiment a one-inch iron plate was placed horizontally in contact with the target, as shown in Fig. 4, and a charge of 75 pounds of dynamite was forced tightly into the angle between the plates and exploded. The result was that the indentation in the target was increased by about one inch, but all the plates and bolts remained unbroken. The ends of the plates curved outward, the outer one

about one inch. The structure was somewhat racked and strained but still remained quite solid. It had as before sprung back about two inches. A portion of the backing on the left, which had been much weakened by bolts passed through it, was broken off and partially displaced. The effects on the backing were somewhat more pronouced than in the previous round, but this was probably as much due to the repeated blows of 440 pounds of dynamite as to the particular position of the charge in the last experiment. The platform of blocks and the iron plate, which in the experiment, represented the water surface in contact with the armor, was de-

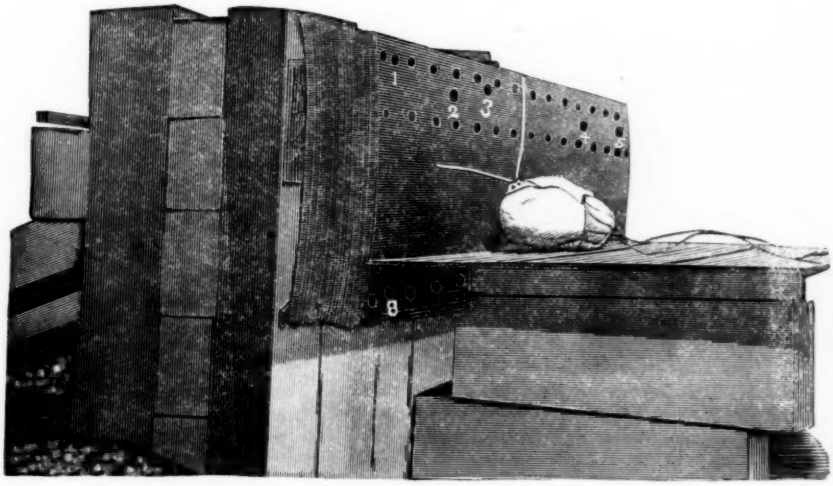


FIG. 4.

molished, the plate being badly torn and the wood pulverized. The result is shown in Fig. 5. Mr. Folger concludes from these experiments, "that it is a matter which hardly admits of doubt, that a modern armor-clad will not be materially injured by the explosion, in superficial contact with her overwater plating, of charges of more than 100 pounds of dynamite." We would add to this that in the case of the breaking up of a projectile before exploding, the explosive material may be scattered over a considerable area and thus diminish the effect produced at any given point.

On turning again to the description of the air gun projectile, it will be observed that, as with nearly all of the shells in use which are to be exploded by impact, the detonator is placed in front of the explosive. As we are accustomed to regard the explosion of our high explosives, when induced by detonation, as instantaneous throughout the mass, it has seemed a matter of no importance, as regards its effect on the explosive, where the detonator was put. Berthelot has, however, advanced the theory that while the reaction started by the first shock in a given explosive material is propagated with a rapidity which depends upon the intensity of the shock, and while this intensity may vary considerably according to the method by which it is produced, yet the pressures which arise from the shock exerted on the surface of the explosive are too rapid to become uniformly dispersed throughout the entire mass, and the transformation takes place locally among the layers first reached. If it is sufficiently violent they may then be heated to the necessary temperature, and they will be immediately decomposed and produce a large quantity of gas. This production of gas is in its turn so violent that the shocking body has not time to displace itself, and the sudden expansion of the gases of explosion produces a new shock,

probably more violent than the first, on the layer situated below. The mechanical energy of this shock is changed into heat, in the layers which it reaches, and produces an explosion: and this alternation between a shock developing mechanical energy which changes into heat, and a production of heat which elevates the temperature of the layers up to the degree necessary for a new explosion capable of reproducing the shock, propagates the reaction, molecule by molecule, through the entire mass. The propagation of the explosion takes place in this way in consequence of phenomena comparable to those which produce a sonorous wave.

In connection with his tests of the dynamite air gun, Lt. Zalinski has also tried exploding dynamite in contact with iron plates. The two experiments reported are as follows: Fifteen seven-eighths inch iron plates were piled upon one another. Upon these an iron canister, containing twenty pounds of untamped dynamite in four paper cartridges was placed.

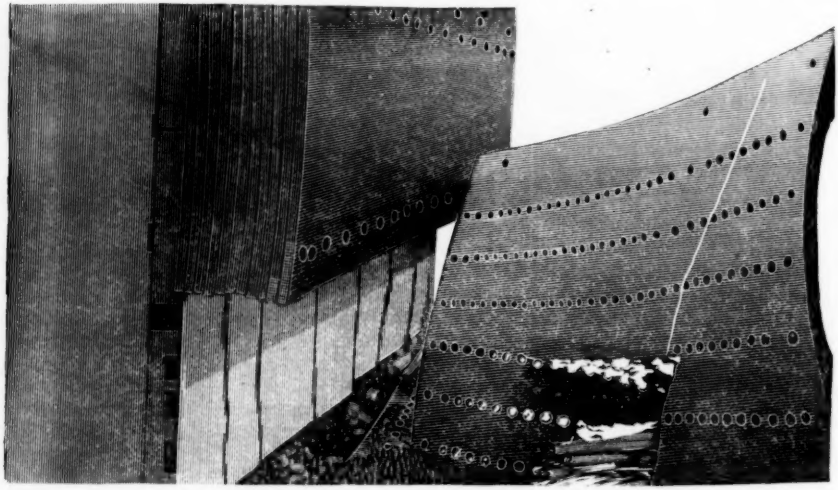


FIG. 5.

In view of this theory experiments were made at the Naval Experimental Battery. Two charges of dynamite of ten pounds each were inclosed in woolen bags, suspended as in the previous experiments, and exploded successively before the one inch iron plate shown in Fig. 6. The two experiments differed only in the fact that while in the first the exploder was inserted in the side of the charge farthest from the face of the plate, in the second case the exploder was inserted in the side of the charge in contact with the plate. The result of the first explosion is shown on the left hand of the figure. The area of the hole was about 192 square inches and the edges were quite cleanly cut. The result of the second explosion is shown on the right hand. The area of the hole was about 96 square inches, and the sides were pushed outward as if subjected to a slow and somewhat continued pressure.

About this the remains of four large iron boilers were placed as shields, and then the dynamite was exploded. The result was that plate No. 1 was shattered, plates Nos. 2 and 3 were crushed, plate 4 fell to pieces when lifted, while 5, 6, and 7 all showed the effects of the blast. The iron boilers were blown to a distance of several yards, while the ground was torn up to some distance.

In the second experiment a pile of fifteen, five-eighths inch plates, was used and seventy pounds of tamped dynamite, enclosed in a cylinder, was placed upon it. The boilers were placed about the pile and the charge exploded. A large

hole was blown through twelve of the plates and the boilers were blown to a distance of thirty yards and riddled.

A somewhat similar experiment in which gun cotton was substituted for dynamite was made by Lieut.-Commander Folger. The target represented in strength the protected deck of a modern armored vessel. Three one-inch iron plates were firmly joined together by eight one-inch bolts. Heavy timbers, serving as a support, were placed upon the ground at a distance of 4½ feet from one another, and the plate was laid horizontally upon them, and fastened to them by two one-inch bolts at each end, which thus added a strength of three-fourth inch of iron.

After a number of preliminary trials to determine the best means for producing a perfect detonation had been made, a charge of 25 pounds of wet gun cotton tied in a bag, with 20 ounces of dry gun cotton and 80 grains of mercuric fulminate as an exploder, were placed on the target. The result of the explosion is shown in Figs. 7 and 8. A hole, 56 square inches in area, was blown through all the plates and a hole, 18 inches deep, was blown in the rather friable earth beneath. The bending of the plates extended from the timbers, without starting the bolts, passed nearly through the timbers. The plates were of the same lot as those used in the other targets at the Experimental Battery, and in order to counteract as far as might be the weakening effect of the bolt holes, plates of iron, one-fourth inch in thickness were inserted on either side of the middle plate, and a third one was placed above the top plate. There was and reached a depth of indent of 7½ inches at the hole. *The area of the base of the charge, before explosion, was about double that of the hole made.* The wet gun cotton used was compressed in the form of discs, and it is a most curious fact that the area of the base of the charge beyond the limit of the hole was indented by the discs of gun cotton in contact with

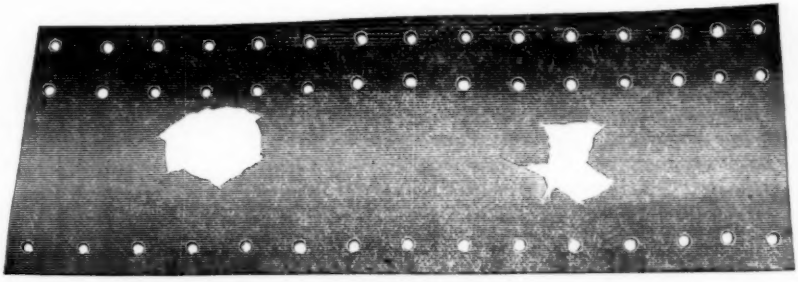


FIG. 6.

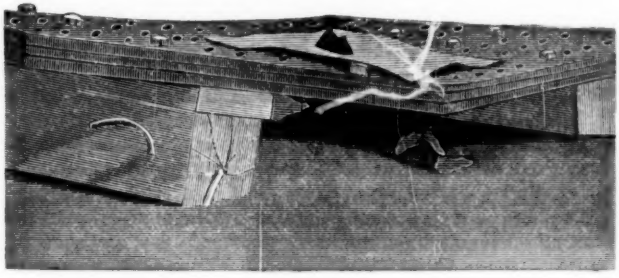


FIG. 7.

the plate before these discs exploded. As the exploder was placed in the top of the charge this observation seems to corroborate the results obtained when testing Berthelot's theory as to the transmission of the explosive reaction. The impressions of the gun cotton discs on the iron plate are shown in Fig. 8.

It will be observed that in each of the last described experiments the plates were far from being rigidly supported, and hence offered less resistance to a rupturing blow than they would have done if well braced. But as the target was arranged in the last experiment it fairly represented the somewhat flexible deck of an armored ship, and showed the degree of vulnerability of the weakest point, and what might result if we could reach that point with our explosive projectile.

FIG. 8.

At the beginning of this article we have said that it had been feared that the high explosives could not be fired in a shell with gunpowder as a motor without danger of a premature explosion in the bore of the gun. Abel, however, has long held other views, and some years ago he publicly expressed the belief that gun cotton could be fired thus without danger, but that no one had the courage to try it. The experiment has now been successfully made with several of the high explosives, and even so long ago as 1874 dynamite was so used under the direction of the Naval Bureau of Ordnance, the experiments on the high explosives made at the Experimental Battery, as reported here, being merely a continuation of these earlier experiments. More recently an experiment is reported as having been made in April last, at Greenville, N. Y., by F. H. Snyder. He fired dynamite by the aid of a slowly accelerating powder and a peculiar buffer devised by him. The cannon used was a brass field piece of about 4½ inches bore. A charge of a pound and a half of powder was put in, and this was followed by a sabot formed from alternate layers of iron, leather, copper and paper, and made to fit the bore nicely. Next to this was a brass ring holding a rubber plug which was perforated with chambers at one end. Next came a long cylinder weighing thirteen pounds and containing five pounds of dynamite in the end. The object in using the perforated rubber plug was to take advantage of the compression of the air confined in the cavities for gradually transmitting the force of the explosion to the dynamite projectile. The wooden sabot of the dynamite projectile was winged so as to increase its accuracy of flight. In

the experiments the dynamite was fired without any premature explosions, but no great range or efficiency seems to have been attained.

Another experiment is reported from Sandy Hook in July last. Here 5½ lbs. of explosive gelatine were fired in an 8-inch dynamite shell. The gelatine was inclosed in a thick pasteboard cylinder, which was divided into four sections by two intersecting partitions. There was a cushion of cork in the shell and a hollow rubber cylinder was placed between the charge and the shell. The paper case and the inside of the shell were well covered with graphite. There was no detonator in the shell, and it was probably intended to explode the gelatine by its own impact. The account of the experiments is meagre, but it said that service charges of powder (35 lbs.) were used for firing the shells. Two rounds were fired. In the first, the shot went successfully to the target, and the point indented the iron about seven inches and exploded, but did no harm. The next shell got as far as the muzzle of the gun and burst in the bore but doing no other injury, apparently, than scoring the rifling. These statements are made as reported, but it is quite probable that the shell broke up in both cases without any explosion of the gelatine.

Experiments in this direction have also been made at the Naval Experimental Battery. Some time since the trials were made with dynamite. In this instance, after a few preliminary experiments had been made (in which twelve rounds were fired using considerable air space, reduced charges, and a small quantity of oakum in the bottom of the shell to serve as a cushion) ten charges of dynamite of 5½ ounces each were fired in 12-pounder spherical shells under service conditions, that is, with a full charge of powder and no air space. There was no premature explosion with any of the twenty-two charges fired, though one shell exploded on impact with the water. Five of the shells carried ordinary time fuses, and these exploded at the point and time intended.

Finally, on August 4, experiments were made at the same place in firing gun-cotton. After five preliminary rounds, ten rounds were fired, at a range of about 2,000 yards, with the 80-pounder (6.4 inch) B. L. R. using full service charges (10 pounds) of powder, and shells filled with wet gun-cotton (3 pounds). The only precaution taken to relieve the shock at starting was in placing a layer of oakum ¼ inch thick in the bottom of the shells. The shells were plugged with wood as if it was dangerous to explode them down the bay on account of the great energy imparted to the fragments when high explosives are used as bursting charges, and as it has been demonstrated in previous experiments that it was feasible to explode gun-cotton shells at a desired range. Three rounds were fired, without fuses, at the target. The gun was fifty yards off, and the velocity of impact was about 1250 f. s. The shells exploded on impact, as was shown by the small size of the fragments, by the fan-like spread of the scoring on the interior of the shelter erected about the target and by the sound of the explosion which was heard. The effect on the target in each case was an indentation about 2 inches deep, with a diameter of 10 inches. No plates were injured. There was no case of premature explosion of the projectile in any of these experiments. It thus appears perfectly practicable to fire with safety, and under service conditions, charges of wet gun cotton from a bore of considerable size.

THE WORLD'S TELEGRAPHS.—The telegraph appears to have made more progress in the United States than in any other country. The number of American telegraph offices in 1882 was 12,917, and the number of telegrams forwarded during the year was 40,581,177. The number of telegraph offices in Great Britain and Ireland in 1882 was 5,747, the number of telegrams forwarded being 32,965,029. Germany had 10,803 offices, the number of telegrams forwarded being 18,362,173. France had 6,319 offices, the number of telegrams forwarded being 26,260,124. Russia had 2,819 offices, the number of telegrams forwarded being 9,800,201. Belgium had 835 offices, the number of telegrams forwarded being 4,066,843. Spain had 647 offices, the number of telegrams forwarded being 2,830,186. British India had 1,025 offices, the number of telegrams forwarded being 2,032,603. Switzerland had 1,160 offices, Italy 2,590, and Austria 2,696. The number of telegrams forwarded in these three last-mentioned countries was 3,046,182, 7,026,287, and 6,626,203 respectively.

THE VENTILATION OF BUILDINGS.

By J. NEVILLE PORTER.

From "The Building News."

One of our most important sanitary requirements is the efficient ventilation of inclosed spaces in large buildings of various kinds, as more dangerous diseases and many more deaths occur from the want of and defective ventilating arrangements of these inclosures than from other insanitary causes. Many persons, who take much interest in sanitary subjects may perhaps question the truth of the statement, on the ground that such a deplorable grievance has not been notified to them in any forcible or even moderately appreciable manner compared with the horrible housing of the very poor, and other leading hygienic subjects. The reason for this grave omission appears to be that very great difference of opinion prevails among sanitarians, architects, builders and medical men concerning defective and efficient ventilation of buildings, and we are pestered with innumerable false and ridiculous opinions on artificial ventilation. I have adopted a novel and somewhat arduous mode of qualifying myself for dealing with the subject. In addition to referring to a great mass of information on the question scattered through numerous British and foreign publications of different kinds, I have inspected the ventilating arrangements of almost all classes of public and other buildings in the Metropolis, Manchester, Liverpool, Birmingham, Wolverhampton, Walsall, Oxford, Cambridge, and other large towns. I have also had consultations with architects, builders, city and borough surveyors, sanitary patentees, and scientists on the subject. Having referred to the composition and vitiation of the atmosphere, the lecturer added: When compartments within buildings are dependent for ventilation from windows and doors only, they are rightly said to be almost hermetically sealed in bad weather, as these apertures cannot then be endured. Many rooms are excluded from ventilation in cold weather, and others again nearly precluded from fresh air by stopping up indifferent and bad artificial inlets and outlets. Moreover, I have noticed many occupied rooms unprovided with such inlets, and some which had no artificial outlets. No room in which there are human beings for hours at a time can be properly ventilated unless it is provided with artificial inlets and outlets of particular relative sizes, and fixed in certain relative positions, and also with efficient means for duly regulating the supply of fresh air admitted through such inlets, and warming it in winter. It would be impossible to lay down hard and fast lines for the various proportions of inlets and outlets, as much depends upon local conditions, the amount of fresh air required in a room according to the number of occupants, the amount of gas consumed, and vitiated air from other causes than respiration and fires and lights, including foul gases from chemical substances, goods stowed in warehouses, &c. It is also essential that there should be no unpleasant draughts from the inlets. Opinions materially differ as to how this requirement should be effected, and, therefore, several means have been adopted for this purpose, nearly all of which have failed. The most difficult inclosed spaces to ventilate are small rooms with low ceilings occupied for several hours by many persons, and having fires, lamps, or gas; and larger rooms in which the cubic space of air to each individual is 500 ft. or less; inasmuch as the air in these compartments should be frequently changed without perceptible movement. Dr. Parkes tells us that "in barracks with 600 cubic feet per head the rooms are cold and draughty when anything approaching to 3,000 cubic feet of fresh air per head are passing through. That is a change of five times per hour for each 600 cubic feet of air space; a change equal to three times an hour is generally all that can be borne under the conditions of warming, or that is practically attainable." The best method of

* Proceedings of the Society of Architects.

artificially ventilating inclosed spaces in buildings not having galleries is by causing the fresh air to enter through grated openings outside the wall at or close to the floor level through each of such apertures; the fresh air should enter a vertical, commonly called a "Tobin," tube, extending about 7ft. to prevent draughts, and close to the inside wall; and in the tube a valve should be fixed to regulate the supply of the incoming air. The natural pressure of the atmosphere, and the additional velocity given to it in passing through a long, narrow pipe, cause it to generally continue as a direct current about equal to the dimensions of the tube for several feet before spreading over the upper part of the room, in which it is warmed and gradually descends to the occupants of the compartment. The height of these tubes should be so fixed that the fresh air from them will not be suddenly deflected by the ceiling so as to fall in a kind of shower before being mixed with the air in the room. Inlet-tubes should be numerous and small, and equally distributed at the sides, or more, if possible, in large rooms, so that the air from them may be properly mixed according to the law of gaseous diffusion. The area of their orifices should also be more than that of the artificial outlets. When one side of a large room does not communicate with the open air, pipes or flues under the floor from the opposite wall-gratings should be led into "Tobin" tubes for the admission of fresh air thereto, as is done in the board room of the Paddington Vestry Hall. It is also highly important that in cold weather the fresh air admitted into large rooms and other inclosed spaces occupied for hours by several individuals should be warmed; otherwise unendurable and injurious draughts will be experienced. If the fresh air cannot be warmed it should not be let in at the skirting or floor level, as it could not be borne in bad weather if it enters at great velocity; nor should the external atmosphere be admitted very near the top of the room, so as to rebound from the ceiling and fall on the head in a shower, and no flap or hopper will prevent this result; consequently the "Sherringham" valve is generally fixed near the ceiling, and admitting the outward air through a perforated brick, or iron plate, and driving it upwards is of very little use, although it often acts as an outlet and can be closed when required. Air inlets through slits in sashes, or through louvre or hopper openings in windows, as frequently noticed in hospital wards, are inefficient for ventilation, as the admitted air is neither warmed nor can be properly mixed with that in the room; therefore severe down-draughts will be felt. The inlet from McKinnell's perpendicular tube at the top of the room is objectionable, as it acts as an inlet and an outlet in a fitful way. When fresh air cannot be directly admitted at or near the floor level on account of the contaminated atmosphere close to its exterior, occasioned by offensive trades or otherwise, pure air should, when practicable, be let in from one or two perpendicular shafts reaching above the top of the building, such shafts communicating with a flue at their base, and led from this channel through tubes or grates into the building at any desired point. The method adopted by Captain Douglas Galton of warming cold outer air in openings at the back of the firegrates, and from thence admitting it into rooms is extensively adopted, and in many respects is appreciable; but his plan would be improved if a portion of the warmed air could be admitted into the center of the compartments through flues or under the floor, inasmuch as the heated air from the openings above the fireplace does not appear to mix freely with the air in the rooms so as to cause nearly an equal degree of heat among the occupants therein. It would not be practicable to cause anything like a sufficient amount of warmed air to be conducted into the room from apertures opposite the fireplace from the Galton stoves, compared with that emitted immediately over the grate, unless the heated air was propelled. I am strengthened in this opinion from the fact that in several of the new barracks where these stoves are used there are Sherringham valve inlets opposite to them and close to the ceiling for the admission of cold air and which is not properly diffused in the room. For this reason the cold air is admitted into the wards of the London Hospital through the numerous apertures in the window sills; the warm air from the back of the fire-grates at the opposite side is

not a good system of ventilation, even if the artificial outlets were excellent. Buildings containing galleries are far more difficult to efficiently ventilate and warm than other inclosed spaces. It appears that the best plan to admit the air into the former inclosures is through horizontal flues or pipes under the floors of the galleries into pillars or into perpendicular pipes connected therewith, so that the fresh air will be admitted over the heads of the people, and thus no unpleasant draughts can be experienced. If the pure air is properly warmed, it may with good effect be also introduced under the galleries as well as above them, and thus increase the more rapid distribution of the fresh air through the building. Under the floor of the Manchester Free Trade Hall a flue is constructed in the brickwork running round the walls. This channel is supplied with fresh air by three large openings from the outside. In the thickness of the wall eighteen vertical flues are carried up, which deliver fresh air into the hall between the ornamental pillars in the gallery and about 18ft. from the floor. From this elevation a sufficient quantity of fresh air can be introduced, and no unpleasant draughts are felt. Single rooms in lunatic asylums, hospitals for the insane, and prisons are generally without any efficient means of ventilation. The inlets to these would be greatly improved if fresh air, with means of warming it in cold weather, were admitted from Tobin tubes or gratings in the walls opposite the doors to these small dwellings. The inlets should be beyond the reach of the inmates, so that they could not be designedly stopped up. When a large quantity of pure air is required to be quickly and continuously supplied for several hours in crowded assembly rooms, exchanges, &c., a fan or fans, propelled by steam, are frequently necessary—a method called ventilation by propulsion—and the fresh air driven in can easily be regulated. If the air enters at a great velocity through small apertures, it will escape at the outlets without properly mixing if the latter be improperly arranged. In the Royal Courts of Justice this disadvantage is prevented by causing the air fanned into the courts to gradually enter them through numerous small apertures in their floors, the velocity of the entry being checked by the air passing through gauze sheets of large area at the openings of the flues up which it passes to the basement of the courts. There has been very much controversy respecting outlets for the escape and extraction of vitiated air within buildings. In small rooms Dr. Arnott's outlet has been much appreciated. It is a valved opening at the top of the apartment leading into the chimney; but it is mainly objectionable because smoke and wind are occasionally driven from it into the room, and also because it is seldom led into a separate extraction flue surmounted by an efficient exhaust ventilator. For large rooms containing a great number of occupants the Arnott outlet is of very little value. Upon inspecting the Municipal Offices at Liverpool, I was told that in some of them soot is blown from the outlets for foul air led into the chimney. The best means for exhausting the contaminated air from a large assembly room and other compartments occupied by numerous individuals where there is no room above, is to provide two, three, or more outlets according to the size of the room in the form of perforated rosettes at the top of the ceiling, or just under the roof, and at about equal distances apart. Each of these openings should be led into a tube, and extend outside the roof about two yards, and be mounted with a cowl or exhaust ventilator, which would act as a good extractor of foul air from, and prevent down-draughts within, the tube. A sun-burner is a powerful abstractor of vitiated air when fixed immediately under a copper cone. By far the greater number of sun-burners which I have noticed fail to answer their purpose efficiently in consequence of being fixed at the end of tubes extending several feet, and in some cases three or four yards, from the ceiling, as in this case much vitiated air remains above them. If a large room has several very small openings in addition to large outlets in the ceiling, as the Birmingham and Cambridge Town-halls, it is advisable to fix exhaust ventilators upon half-a-dozen or eight tubes from the roof, to take away the vitiated air from the roof space. The sides and top of the roof, except the tube apertures, should be sealed. By these means the foul air would soon be extracted from the rooms

below, and downdraughts prevented. Again, in a theater which has only one important foul-air outlet in the ceiling (like that at Covent Garden), above an immense chandelier, it would be much better to stop up the numerous small apertures in the roof intended for the escape of vitiated air from the theater, and fix cowls or exhaust ventilators on about half-a-dozen tubes, as just mentioned, rather than have one or two vertical tubes over the large outlet led above the roof similarly mounted, as the former outlet pipes would have far more exhaust effect, and be more likely to prevent down draught to the auditorium. Another method of withdrawing contaminated air from large compartments is by upcast open shafts of large dimensions, to which outlets from the ceiling or at the top of the sides communicate by horizontal flues. This arrangement has not sufficient power to abstract the vitiated air from all the artificial outlets connected with these channels, but only from those nearest to the shaft, although it may be intensely heated by steam pipes or coke fires for additional exhaust effect. It is essential, therefore, when practicable, to have as few openings as possible as outlets, and these should communicate with as many perpendicular shafts as can be reasonably constructed, a plan which has been more extensively adopted during the last four or five years. In the new examination rooms of the University of Oxford, two upcast shafts of large dimensions are made to extract the contaminated air from the large writing rooms, both of which have two rows of perforated rosette outlets, which communicate with the shaft connected therewith by a large longitudinal lath and plaster duct running between the outlets, from which the foul air enters by cross channels. In addition to this disadvantage, the shafts appeared to be open at the top, whereby they are rendered sluggish in their exhaust effect, and cannot prevent down draughts. To make such large shafts as efficient as they can be, they should not only be intensely heated, but extend like a tower above the buildings to be ventilated, in order to increase the velocity of the up draught, as is the case with the large ventilating shaft of the Lancashire County Prison at Manchester and the London Hospital. These shafts should also be mounted by a first-class exhaust ventilator. The system of attempting to withdraw vitiated air from many openings at the top of a room and led into an upcast shaft was adopted at the Manchester Athenæum, but had to be given up in favor of vertical shafts over the room outlets as far as practicable. In the Royal Courts of Justice, while the means of warming and cooling the fresh air and supplying such to the Courts appear to be very good, the arrangements for abstracting the foul air are very indifferent, for several reasons. In the first place, the eight vertical exhaust shafts were, when I recently inspected them, about 2ft. below the level of the roof, and therefore, though heated by coils of steam pipes at a high pressure, they lose much of their extractive force. I understand that application has been made to heighten them about 2ft. or 3ft. Another cause for the ill-ventilation of these new Law Courts is that the low shafts referred to were until recently open at the top, so that if draughts did not descend in the Courts from them, they were very sluggish in their abstraction of vitiated atmosphere. I am informed that these defects have been remedied by covering the tops of the shafts, and causing vitiated air to escape from side openings. This method is not anything like as efficacious as superior exhaust ventilators would be, and the sooner these are used the better. The defective ventilation of these Courts has also, in some measure, been occasioned by numerous cracks in the flat wooden roofs, whereby cold air has descended below and produced great draughts. Sudden gusts of wind frequently blowing in the doors of the public galleries from the corridors communicating with them has been another cause of the ill-ventilation of the Courts. To diminish this evil I suggested that double doors should be provided in these passages. I think the best outlets for large rooms with others above are perforated rosettes in the ceilings, which openings should be connected with as many vertical shafts as practicable, and surmounted by exhaust ventilators. Another class of suitable outlets to this class of rooms are square grates at the sides, leading into perpendicular tubes through upper apartments

to the outside of the roof. Outlets in the middle of compartments which communicate with louvre openings, either in turrets or lanterns, or at the sides of the roof, have no extractive power, and wind and often rain, is driven into the rooms below. In a great number of buildings I noticed that this kind of openings were the only artificial outlets for vitiated atmosphere into the open air, and was frequently informed that such apertures had been closed in bad weather, as the down draughts from them could not be tolerated. One of the officials of the Rev. C. H. Spurgeon's Tabernacle said that on cold mornings and evenings, when the windows and doors were closed in this mammoth chapel, and several hundred lamps were lit for illuminating and heating, some of the large air outlets communicating with louvre openings in the roof had to be closed to prevent unbearable down draught. Again, the Lecture Theater of the London Institution in Finsbury Circus has no outlet in the dome, and but very bad ones in the ceiling, which lead into the roof space, and are often closed on account of severe down draughts from the louvre openings at the top of the roof, intended for the escape of vitiated air, so that this room, which is frequently crowded, is often without ventilation, and especially as the numerous inlets under the seats for atmospheric air appear to be sealed with dust and dirt, occasioned by the smallness of their apertures and the inefficiency of the channel through which attempts are made to supply the room with external air. It is much to be regretted that the efficient ventilation of buildings has been greatly retarded by the erroneous decision of the sub-committee of the Sanitary Institute of Great Britain respecting exhaust ventilation cowls, but which conclusions have been fully refuted. Among the numerous ventilating arrangements which I have noticed for the ventilation of rooms and other inclosures in buildings there are several which have efficient artificial inlets and outlets; but a good system of both is not often found. It is very invidious to particularly mention whose method of ventilation is the best; but if pressed for an answer I should say that the most efficient and satisfactory means adopted to ventilate a building under a system by carefully adjusting the size and relative positions of inlets and outlets is that originated by Mr. Banner at the Council Chamber at the Guildhall in the City of London in 1878, and which was closely imitated at the Hall of the Royal Institute of British Architects in 1879, and subsequently at the Long Room of the London Custom House. It has just been adopted with great success at the Board Room of the Paddington Vestry and other buildings. The prize of the Society of Arts, in 1882, was awarded for the best sanitary arrangements in houses within the metropolitan area for the residence of Sir Daniel Cooper, Bart., 6 De Vere Gardens, where I found the Banner ventilators have been fixed and the system applied for the ventilation of the drains and other parts of the house, and which appliances are very satisfactory. I have also received very favorable notices from the officials of other buildings in which the system is used. The Banner exhaust ventilators appear also to be the most efficacious in use. Fresh air may be warmed for rooms and other inclosed spaces by hot-water pipes, by steam pipes, and by hot-air chambers. The advantages of heating air by the circulation of hot water in pipes are several: firstly, the temperature within the tubes is maintained six or eight times longer than in steam pipes after the boiler fires are extinguished. Again, the supply of heat required in any room can be regulated by valves in hot-water pipes; while in those containing steam we must have the whole or no heat from such, unless means are provided for a supply of cold air to be mixed with the warm air before being admitted within compartments, and which is very difficult to adjust. This being so, and as the heat from steam pipes is at the least about 212°, and often more, it is greater than can be generally borne. On the other hand, the heating surfaces of hot-water pipes are limited to about 160°, as the temperature of the water in the boilers to feed them seldom exceeds 200°, and the pipes are of larger dimensions than those for steam heating. Moreover, the cost of fuel is less for hot-water than for steam pipes, while the former are free from the danger of explosion. For buildings continually occupied it is nearly always better to heat the air by hot-water

pipes; but for warming cold air admitted into factories and workshops where steam is used, and for heating large foul-air extraction shafts, steam pipes are more useful than hot-water tubes. The Royal Courts of Justice are heated by hot-water pipes on the low-pressure system, while steam coils are used in the outlet shafts to create an intense heat therein for better abstraction. The supply of fresh air to rooms which have been heated by its contact with metallic surfaces exposed to coal fires is not as wholesome as exterior air warmed by hot-water pipe. The Galton stove, from which heated air is admitted into the room from the back of the fireplace is a very good hot-air apparatus for use in hospitals, barracks, or other large buildings, if it is fixed in the middle of the room. Mr. Constantine's convoluted stove, as used for warming the fresh air admitted to the Manchester Exchange and Free Trade Hall, is also very appreciable. There are also some very useful appliances invented whereby the fresh air can be heated at the inlets close to the walls by gas pipes, and whereby the products of combustion are not driven into the rooms. Opinions differ as to the position in which the heating pipes and stoves should be fixed. It is sometimes desirable to have the warming appliances in the basement, and admit the fresh air therein through tubes at or a little above the floor, or through grates at the skirting. In other cases the air may enter or pass over the heating apparatus in the middle or at the sides of rooms, or between the gratings outside and the inner walls. Heated pipes are frequently run round churches, chapels, and schools and other rooms, while more than half the places of worship are only furnished with the American "Cockle stove," whereby cold air descends upon the heads of congregations; and to lessen this evil the inlets are often stopped up, and numerous gas jets lit to warm the edifices. To these grievances must be added defective or no artificial fresh-air inlets, a large area of glass surface, and draughts from open doors. Coils of steam pipes appear to be the best means of heating fresh air entering large rooms at or a little above the skirting. A great deal has been said by patentees and others in favor of filtering fresh air before being admitted into rooms, in order to prevent dust or "blacks" being driven therein. For this object fine wire gauze, muslin, cotton wool, and thin porous flannel have been placed in the opening in the wall or tubes connected with them; but these materials have so soon got choked with dirt that they have prevented or greatly interfered with the admission of the air. Other means adopted with the view of preventing dirt being driven through inlet tubes, by fixing boxes filled with water in holes in the walls close to the grated openings, and whereby the fresh air is deflected by plates over the surface of the water before going up the tubes, are of very little practical use for stopping dirt entering, as only a very small quantity of the air comes in contact with the surface of the water and soon evaporates. The best plan to prevent floating particles of dirt entering rooms from the tube openings is to clean them well at proper intervals. The thin film of water propelled from several sets of extremely minute jets through which the air is drawn by fans for the ventilation of the Royal Courts of Justice, and several other contrivances of nearly the same kind adopted in the system of ventilating large buildings by propulsion, as St. George's Hall at Liverpool, &c., free the air from dust and "blacks," but the expense of this method of air filtering will prevent it from being extensively adopted. The means used for cooling the air for these buildings, by passing it through extremely cold water, are very appreciable; but other methods adopted for this purpose, by passing fresh air over receptacles filled with ice, are of little or no advantage, as only a minute part of the admitted air comes in contact with the ice, in the same manner as only a very small volume of sewer gas is purified by Mr. Baldwin Latham's charcoal filters, intended to purify the whole.

Mr. W. P. Buchan, of Glasgow, in opening the discussion on the paper, remarked that Mr. Porter had treated his subject exhaustively, and in many of the conclusions arrived at, he coincided with the lecturer. He agreed with the recommendation to provide exhaust shafts to outlets; for, unless the exhaust was a powerful one, the air in an occupied room

would still remain vitiated, notwithstanding the provision of ventilators. The outlet should never be placed low down in a room, as all the air in the space between it and the ceiling remained unchanged, and was the most vitiated in the room. Often, by raising the level of an outlet he had removed a persistent bad smell from a room. He did not see why Mr. Porter should have gone out of his way to speak exclusively of the Banner system. He understood that at the City of London Guildhall the Banner system had been condemned and replaced by another, and if that were the fact, he did not know why Mr. Porter should have been so anxious to commend the system and have quoted this instance of its use. He should be glad to hear particulars as to the test applied, and the system tried before the Society of Arts medal was given to this system. Could the lecturer say whether Mr. Banner carried out the system in the way described in his book on "Wholesome Houses," and as advertised? For, if so, it was not clear how the medal of the Society of Arts could have been given deservedly. He should much like to see the system in action. Heating in connection with ventilation deserved more attention than was usually given to it. It was useless to talk of providing more efficient ventilation for the dwellings of the poorer classes; what they wanted was to conserve heat as far as possible on account of their inability to buy fuel; and if any system could be devised for heating groups of this class of dwellings from one central fire it would be a great benefit. He concurred with Mr. Porter that hot-water pipes were more healthful than highly-heated steam pipes, and these again were much superior to any form of iron stove. Conical ventilators were very useful, and were the subjects of many recent patents, although as a matter of fact, they were first recommended by Mr. Philbrick, architect, in a letter which appeared in the *Building News*, in 1870, 1871, or 1872, long before the earliest of these patents were taken out. A valve-box should be provided to every outlet, to prevent down draught.

Mr. Welman thought a description of the best mode of ventilating the ordinary dwelling would have been more useful to most architects than the full details and criticisms Mr. Porter had given as to the new Law Courts. He was not a believer in the exhaust ventilators, as they occasionally acted as inlets, when they were of dubious advantage. He also had little faith in Tobin's ventilating tubes, as they were wrong in principle; they directed the supply of fresh air to the ceiling, where it mixed with the foulest air in the room, always accumulated at that level, and then descended. It was a mistake to aim at making the walls of houses impervious to the passage of air by lining them with an air-proof composition. The aim of sanitarians should be to render them more porous than at present, so that the side of the house on which the wind blew should be an inlet, and the opposite side, on which there would be a partial vacuum, should be an outlet. He had not yet worked the idea out; but if some means could be adopted for warming the incoming air in such a hollow wall, it would be a step in the right direction.

Mr. E. C. Allam, of Romford, said, that while theoretically everybody approved of the fullest ventilation, practically the first endeavor was to close any ventilator within reach so as to prevent draught. He differed entirely from the last speaker in his advocacy for porous walls, for he regarded them as most objectionable. Outlets in public buildings should be placed high up, but the inlet should not be too low down, or the fresh air would remain close to the floor level. The vertical tubes answered very well, and seemed the best system yet adopted. The treatment of small rooms was a more difficult problem, and he should have liked more information as to the subject from Mr. Porter. The outlet of a room was necessarily very low down—the fireplace, and any attempt to place it higher only gave rise to complication. For admitting fresh air, a good plan he had found was to provide an opening just over the architrave of door, deflecting the current upwards by hanging a picture in front. He preferred, for warming purposes, hot air or steam apparatus to hot water, as with either of the former you could warm and ventilate at the same time.

Mr. P. J. Davies found the best pla

of ventilating a dwelling room was to introduce the fresh air at back of fireplace; he had adopted this plan since 1868, and had never known it to fail. No system of warming answered so well as the one on the hot-water principle, which provided perfect ventilation; an excellent method was to carry the hot-air flue behind the skirting, perforating it with very small holes. He could not understand why Banner's system of ventilation should have been set up by the lecturer as the best, when there were Buchan's, Boyle's, and many other systems equally good.

Mr. Lindsay had found, for equable warming and ventilation of the rooms of the poor, an excellent plan was to carry the partition dividing the apartments on a floor no nearer to the ceiling than was necessary.

Mr. G. H. Guillaume supported the suggestion of Mr. Welman as to the value of porous walls, and referred to Dr. Pettenkofer's experiments as to the transpiration of air through walls. It would be well if something could be done to obviate the unsightliness of cowls—he would not mention the names of any—and he thought architects might do something in this respect. He suggested that the discussion might be resumed at an early meeting of the society.

Mr. Ellis Marsland asked Mr. Porter if he could explain why inlets should be larger than outlets. When he commenced practice he had to ventilate a room, and after reading up books he carried out a scheme. He invited the committee to inspect the work, but before they came he thought it well to privately test it. On the day when he took his anemometer down to the room it was very windy, and the plan worked well; but when the committee came it was a damp dull day, and the anemometer would not work. (Laughter). He found that the system of bringing in air 7 ft. above the floor answered well if the air was heated as it was brought in; but the outlet should, he believed, be larger than the inlet.

The chairman, in closing the discussion, remarked that the problem of ventilating living rooms was very difficult, as the conditions when the fire was lighted and when it was unlighted were just reversed. His experience had shown that when the acoustics of a public room were bad, the ventilation would be found to be defective, and when he had remedied the latter he had always found that people could hear better in the room. An excellent plan often adopted now-a-days was to put a broad beam at the bottom of a window so that it could be raised to admit air at the opening. If the window went well up to the ceiling level, a broad beam should be placed at the top, having in it a perforated zinc band with the rough edges outside, like the surface of a nutmeg grater; the air would then easily pass out, but would not so readily be admitted. Outlet shafts should always be provided with some means of propulsion, either a gas-jet or a water-fan.

Mr. Porter, in replying upon the discussion, said the chief points had been with regard to house ventilation and the inlets and outlets of public buildings. The inlets should always be larger in area than the outlets, in order that the in-currents might have greater propelling power. In most public buildings the inlets were proportionately much too small. Louvre ventilators were no good at all; there were always down draughts from them unless a gas-flame were maintained at the foot of the shaft. He had not treated of house ventilation in his paper, which was confined to public buildings. The Arnot ventilator for an outlet, and an ornamental hopper over door, acting as a "Sherringham" valve, would act efficiently in a dwelling room. For the drawing-room and dining-room a good plan was to provide an opening in chimney breast with separate flue carried up in front of chimney. He could not go into the ethics of advertising ventilating systems; he had simply mentioned the "Banner" system as one with which he was acquainted. He believed that at the City Guildhall another inventor was allowed to make alterations after the "Banner" system was fitted up; but, instead of improving matters, an opposite result had ensued.—A vote of thanks to the lecturer concluded the proceedings.

THE APPLICATION OF ELECTRO-MAGNETS TO THE WORKING OF RAILWAY SIGNALS AND POINTS.

By ILLIUS A. TIMMIS.

From "Iron."

The object of the present paper is to describe a new, powerful, and economical electro-magnet, capable of exerting its pull in a manner suitable for convenient application to the mechanical working of railway signals and points. Its main features are its great power, which is exerted through a long range, and is under perfect control; and its economy, both in exerting the initial pull which effects the mechanical movement required, and also in retaining the moving parts after the desired movement has been effected. The rapid growth of railway systems and their consequent complexity have rendered urgent the application of electricity for the working of railway signals and points, and for checking the work done by signalmen and pointsmen. Though much has been accomplished in this direction, both in this country and elsewhere, there has hitherto been always one initial want, namely, an electro-magnet, which, with a low average current and a small electromotive force, shall give a powerful, long, and well-balanced attractive pull. A range of pull of only half an inch, which has hitherto been the practical limit with electro-magnets, is evidently not long enough to be of use for heavy mechanical work, such as pulling signal-arms over or throwing machinery in and out of gear; and although the range can be increased by multiplying gear up to two or three inches, yet the increased current then required for making the attraction powerful enough at the initial half inch distance is so enormous that two difficulties present themselves which are almost insuperable—firstly, the expense; and, secondly, the destructive violence of the final impact, in consequence of the attraction increasing inversely as the square of the distance of the armature from the magnet, and for part of the stroke inversely as the cube. In the ordinary form of the electro-magnet, a core or bar of soft iron, wrapped around with a coil of wire or tape, and bent to the shape of a horse shoe, attracts to its poles a plain armature; and, by some natural law, as yet unsolved, the working pull of such a magnet practically ceases, as already stated, when a distance of only half an inch between the magnet and the armature is exceeded. In the electro-magnet of tubular form, thence called a solenoid, a hollow core or tubular bobbin of brass is wrapped around with wire or tape; and a central rod of soft iron, sliding lengthways inside it, forms the armature, which is drawn or sucked longitudinally into the core by the attraction of the bobbin coil, until it reaches a central position in relation to the magnetic field; in this position the attraction is symmetrical in all directions, and is therefore neutralized. Although a considerable length of attractive pull can be got with such a magnet, the current of electricity required to give any strong initial pull is so excessive that its cost is prohibitory; moreover, it is clear that the holding power falls to zero when the armature reaches its central position longitudinally. In order to obtain adhesive power, or what is called a retaining pull, the internal sliding rod or armature is made shorter than the length of the hollow bobbin, and is capped at one end with a disc of soft iron, which, coming in contact with that end of the bobbin, thereby prevents the armature rod from reaching its central or neutral position within the bobbin, and leaves a corresponding reserve of holding power against the end of the bobbin.

Currie Long-pull Magnet.—In the long-pull electro-magnet, the invention of Mr. Stanley Currie, the principle adopted is a combination of the horse-shoe magnet and solenoid, with additions; but the construction is so materially modified as to give far greater power and efficiency, and the magnetic attraction is more evenly distributed over a longer range, while the initial pull is stronger, and acts

* A paper read before the Institution of Mechanical Engineers.

at a greater distance than in any other electro-magnet of the same weight and with the same current. The range already attained in practice is 3½ inches, and can be increased. The bobbin is made with a tubular core of soft iron, and the coil of wire wound around it, colored red, is surrounded by an outer casing of soft iron, of the same weight as the core, with a soft iron base plate at the bottom of the bobbin, connecting the core with the outer casing; a brass plate covers the bobbin at the top. The copper wire used in the coil is No. 18 Birmingham wire gauge, or 0.048 inch thick. The armature consists of three portions, each one playing its part in the work to be done. The central stalk of soft iron is rather shorter than its own range of motion, and is encased in a brass tube, which is prolonged below it so as to form a guide, fitting within the bobbin core. The soft iron cap or disc, fastened on the top of the central stalk, is slightly larger in diameter than the outer casing of the bobbin. It is made by preference of two or more thicknesses of flat plate, to assist in demagnetization, but it must be thick enough to prevent saturation with any working current. Around the edge of the disc runs a cylindrical rim or flange, projecting downwards; it is so shaped as to suit the attraction required, and it comes within the range of attraction of the outer casing of the bobbin when the lower end of the central stalk has entered within the core. When the rim in turn has done its duty, the disc comes within range of attraction of both outer casing and inner core.

Uniformity of Pull.—So long as the central stalk or armature rod is altogether out of the bobbin core, the attraction upon it continues to be inversely as the square of its distance from the bobbin; but as soon as the end of the iron rod enters within the orifice of the core, the force of attraction becomes lost upon so much of its length as is inside the core. The same diminution in attractive force holds good in regard to the flanged rim of the armature disc, as soon as its lower edge passes below the upper edge of the bobbin. The force of attraction varies also directly as the mass of the body attracted. Advantage is therefore taken of these two principles in combination to regulate or adjust the effective attraction in such a way as to obtain some sort of approximation towards uniformity of pull throughout the 3½ inches' range of stroke of the armature. This is accomplished by tapering the lower end of the armature stalk, and also of the flanged rim, according to the desired adjustment of the attractive force, in addition to which the thickness of the armature disc, and the distance that its flanged rim projects downwards, as well as the thickness of the rim, can also be varied; and in some cases, moreover, the bottom edge of the flange is made of a serrated or wavy form, so as to prevent the pull from suddenly increasing as the disc nears the bobbin. The result is, that when the strength of the pull on the armature stalk and flanged rim is decreasing, owing to their having both of them reached and passed the position of maximum attraction, the pull on the disc is increasing as it nears the magnet head. In this way, and in combination with a counterweight acting at a suitably varying leverage, an approximately equal pull is obtained through a considerable range, and violence of contact in the closing of the disc upon the magnet is avoided. By suitably adjusting the several proportions of the various parts, the pull can be so greatly varied both in force and range that it can be adapted to meet almost any requirement.

Double Length of Pull.—A double length of pull is readily obtained by the simple tandem combination. Here a pair of single magnets on the foregoing principle, arranged at a fixed distance apart, have their armature guide-rod in common; the lower armature disc is made fast upon the rod, while the upper disc bears against a shoulder upon it. The range of the lower disc being nearly double that of the upper, the first half of the pull is given by the upper; and by the time the upper disc has closed upon its own bobbin, it has brought the lower disc within the attractive range of the lower magnet, by which the second half of the pull is then given, the armature rod now sliding free through the upper disc. This arrangement is suitable for working signal arms that are required to stand at the three positions of danger, caution, and line clear.

Railway Signals.—In the application

of the electro-magnets to railway signals, the ordinary signal posts and arms are utilized; but it is advisable that the bearings and working parts should be made as true as practicable, because, though friction is not so material when the work is done by manual labor, it is of the utmost importance that it should be reduced to a minimum where electricity is the motive power. As there are no complicated parts, and the movements are all simple and direct, there is no difficulty on this point. In the application of a single magnet to an ordinary signal-arm intended to stand in only the two positions of danger and line clear, the magnet is fixed upright on a bracket at the back of the post, and a chain from its armature pulls upon a quadrant arc, centered on a horizontal spindle above it. The quadrant carries a lever and counterweight, acting in opposition to the pull of the magnet; and also an arm which is connected by a rod, colored red, with a bell crank centered at the side of the post. Another rod, colored blue, connects the bell crank with the semaphore and spectacle. When the magnet is out of action the semaphore is held up at danger by the weight of the spectacle in conjunction with the counterweight on the quadrant lever, which then comes against a stop. In this position all the parts are locked, in consequence of the quadrant arm being then on its dead center; that is, the quadrant arm and bell crank are so arranged that the direction of the rod (colored red) connecting them passes them through the center on which the quadrant turns. For yet greater security of locking it is preferable, indeed, to let the connecting rod be even a trifle beyond the dead center, so that any pull upon the bell crank, from wind pressure or accumulation of snow on the semaphore, shall hold the counterweight lever still more firmly against its top. The locking is thus done mechanically, and is independent of the magnet. On bringing the magnet into action by a current from the signal box, the pull of the armature rotates the quadrant arc, raising the counterweight and spectacle and lowering the semaphore; in this position the semaphore is retained so long as the electric current is continued. On the cessation of the current the semaphore is automatically raised again to danger, and locked there mechanically without the use of extraneous catches, which is a most important feature. In the application of the double magnet or tandem arrangement to a balanced semaphore centered at mid-length, the pair of magnets are fixed on one side of the post, and the quadrant arc on which they exert their pull is fixed on the spectacle spindle. A rod (colored red) connects the spectacle with a crank on the semaphore, and the weight of the spectacle brings the semaphore to the horizontal position of danger, in which it is locked mechanically as before by the connecting rod being then on its dead center. An electric current sent to the upper magnet pulls the semaphore to an angle of 45° for caution, and a second current sent to the lower magnet pulls it vertical for line clear. In either position it is held by the spectacle acting as a counterweight against the retaining pull of the magnet.

Electric Current.—Under ordinary circumstances a current of 3 amperes is amply sufficient to pull the armature down upon the magnet, and so actuate the semaphore; but to guard against wind pressure, dust, rust, and wear of rubbing parts, a current of 5 amperes is provided. In addition, a reserve current of as much as 15 amperes is kept in store at the signal box, and is at the immediate command of the signalman in any emergency. With 5 amperes an initial pull is given of 8 lbs., at a distance or range of 3½ inches, which is more than double what is required to work any signal arm properly fitted, and the home pull is 321 lbs. If the same strength of current were necessary to hold signals down as to pull them down, the use of a continuous current would be prohibited by its cost. But a current of only 0.1 ampere is more than sufficient to hold a signal down; and it is found that a continuous current of 5 amperes for moving the signal, and of 0.1 ampere for retaining it, yields an economical result. Accordingly, when the armature has finished its stroke and moved the signal, it is made to switch in automatically a resistance coil which reduces the maximum or moving current of 5 amperes to the minimum or retaining current of 0.1 ampere. The resistance coil can take the form of an incandescent lamp, which then serves as an indicator or tell-tale in the signa

box. In excess of the greatest possible requirements, it may be assumed that the whole time during which each signal is needed to be held down to show line clear is twelve hours out of every twenty-four; and that the number of times each signal has to be lowered in the twenty-four hours is 150, and that the time occupied in each lowering is two seconds. Assuming also 10 amperes instead of 5 as the moving current, and 0.2 ampere instead of 0.1 as the retaining current, then 150 lowerings $\times$ 2 seconds $\times$ 10 amperes $=$3,000 ampere seconds, or 0.8 ampere hour; and a retaining current of 0.2 ampere for 12 hours$=$2.4 ampere hours; the total is, therefore, 3.2 ampere hours of current C per signal per 24 hours. The resistance R being taken at 5 ohms, the electromotive force E is equal to $C\times R=3.2\times5=16$; and assuming 746 watts $=1$ horse-power, the horse-power is equal to $C\times E\div746=3.2\times16\div746=0.07$ horse-power. The cost of providing a current of such power by means of a secondary battery, according to well-recognized electrical data, would be only 0.4 penny, while the current actually used being only about one-third of that provided, and the real time less than one-half, the true cost would be less than one farthing per signal arm per day. The foregoing remarks respecting the electric current employed to actuate the magnets apply to the use of secondary batteries; and the results obtained from these accumulators of electrical power are very satisfactory and economical. In certain cases, however, it may be preferred to use a primary battery, such as the Lalande oxide of copper battery, the working of which is very easy and reliable. The constant and economical current it gives can be used not only for actuating the magnets, but also for lighting the lamps on the signal posts and at the points.

With a primary battery the reduction of the current from a moving to a retaining current cannot be effected in the same way as with a secondary battery by switching a resistance in; but the same levers and switches are still available for switching out the large battery which gives the stronger moving current for lowering the signals, and switching in a smaller battery, of smaller cells and with greater internal resistance, which gives the weaker retaining current for holding the signals down.

Railway Points.—The magnets and gearing for working a pair of railway points are practically of the same construction as for working signals, but are of larger size, and are wound with copper tape instead of wire, in order that they may take a maximum current with a minimum of resistance. With a current of 23 amperes and an electromotive force of 40 volts, the force of the pull commences with an initial pull of 33 lbs. at 3½ inches distance, and increases to 54 lbs. at 3 inches, and to a home pull of 1,064 lbs. The points are pulled over and held in either position by a sliding rod, which is worked by a lever and is locked by a locking bolt. The slot in the rod is made ½ inch longer than the width of the lever working in it, so that the first ½ inch of travel of the lever withdraws the locking bolt by means of an incline on the extremity of the lever, before the lever acts upon the sliding rod. Where a pair of points are covered by a signal, the locking bolt, in conjunction with the armature of the magnet which pulls the points over into the position corresponding with the signal when down for line clear, completes the circuit, which enables the signal man to lower the signal. The signal is checked by its automatic repeater in the signal box. The other point-magnet completes with the locking bolt the circuit which works a repeater in the signal box.

Advantages.—The advantages of working signals and points by this system are that their distance from the signal box is immaterial, inasmuch as the electric working gets rid of all the mechanical difficulties which arise from excessive expansion and contraction of lever wires and from the severe pull required to work them through long distances.

Signals.—It is only during the continuance of the electric current that the signal can be held at caution or line clear; its normal position is at danger, to which it returns automatically on the cessation of the current, or if anything goes wrong; and in this position it is locked by simple mechanical means, and not by any electric agency whatever. Each signal is locked by its own magnet, and has a repeater or tell-tale in the signal box in the shape of a small

arm. If it is desired, the repeater is arranged to show the exact travel of the magnet armature working the signal; that is, if the armature stops half way, the repeater arm would stop in the same position; in fact, any arrangement that may be desired can easily be effected. At the instant of contact between the armature and the magnet, there is a momentary cessation of the main current; and the tell-tale arm indicates this by falling back a little from its extreme position. This affords another infallible check as to the correct working of the magnet. The reduction of the current from a moving to a retaining pull takes place automatically at the moment of the armature reaching the magnet.

Points.—The advantages in working points by these electro-magnets are as great as in the case of signals. Either can be worked at any distance from the signal cabin. There is no need for a cabin to be put up, or a stand of levers, to work any special set of points and signals; any number of points and signals can be worked from a small cabin, and can be locked and interlocked with absolute certainty. They can be so arranged that, if any wrong lever is moved by the signalman in arranging any combination, an alarm bell is rung in the cabin, and the signals already lowered go back to danger, the mechanical and electrical parts being so arranged as to provide a perfect check, without the intervention of manual labor or the will of the signalman.

Application to Railway Junctions.—In the application of this electric system to working the signals and points of an ordinary junction where there is a double line of way both on the main line and on the branch, the signal box is divided, as regards the electrical connections, levers, and switches, into thirteen divisions. For station to station signaling the transmitter and receiver instruments are used in somewhat the same way as in ordinary railway working. The continuous current used makes the working very simple, and easy and reliable. The signals and points are actuated by a main current, and this is checked and controlled by a subsidiary current, which works the transmitter and receiver instruments. A train traveling along any section of line protects itself by passing over contact levers or treadles, both on entering and on leaving the section; the depression of the treadles by the deflection of the rail breaks the current which holds the signal-arms down, and sets them free to fly up to danger automatically.

Mr. Timmis desired to add that he had had the signal working in his office in Westminster for a considerable number of months without the slightest hitch of any kind; and at the Gloucester wagon works there were five signals—a distant, a home, and three station signals—all actuated by an electric current from a secondary battery. They had been worked during very severe thunderstorms and gales, and the result was to demonstrate that no electrical disturbance could affect the working of the signals either by a primary or by a secondary battery. They had also had a set of points sent to Gloucester by Mr. Owen, of the Great Western Railway, to fit up and work with their magnets, and no difficulty had been experienced in pulling over the points at any time under any conditions hitherto met with. It might be objected that they would not pull over in heavy snowstorms, but points had now to be watched at such times, and there was no more difficulty (indeed not so much) in working the points electrically than there was by the present manual methods. Last spring the manager of the Swansea Dock and Harbor Trust had asked him to fit up a signal lamp on the ground. There was an objection to signal ground lamps because they were sometimes kicked and injured by loafing navvies, and he therefore suggested putting up a small signal, five eighths of the ordinary size, at such a h. ght that when the arm was down the point should be rather over 7 feet from the ground. That signal had been fitted up about four months, and had been regularly working without any hitch. The point he desired to emphasize was, that if anything did go wrong the signals went to danger. Mr. Currie, by means of an exhaustive series of experiments, had shown that by using an intermittent instead of a constant current, four times the strength of current could be sent without injuring and heating the wires. When in a signal cabin, a signal, lowered to enable a train to leave a given station, was set to "dan-

ger," the train passed what was called a contact breaker. Treadles were not used, because it was impossible to get a perfectly reliable one for an electric current, but there was no difficulty in making a contact breaker which would break the contact with absolute certainty. Mr. Timmis then exhibited one of his signals with the electric apparatus, and illustrated their mode of working.

Mr. Crompton congratulated the author on the successful manner in which he had worked out a very intricate subject. They were, he believed, on the eve of a great change in regard to the mechanical transmission of power. Much of what was now done by ropes, chains, rods, and by hydraulic power, would be accomplished by electrical transmission. A great deal had already been done in that direction, for electric lighting was nothing more than the electrical transmission of power. The results achieved by Mr. Timmis were, however, regarded by many in much the same light as the early performances of the gas engine, which were supposed to be only fit for working churning machinery at an agricultural show. Electric magnets were looked upon as mere toys, capable only of working small signals; but when it was seen that a 4-inch continuous pull of 400 lbs. could be obtained at a distance of several miles with an apparatus weighing less than 1,200 lbs., some idea could be formed of the value of the transmission of power by electricity. But the weak point in the author's project was the difficulty of providing an electric current along a line of railway. When that was done the thing would be easy enough, but how was Mr. Timmis going to charge his secondary batteries? He did not think there was much to hope from primary batteries for those electric currents. They would be very expensive to work, and even the battery mentioned by Mr. Timmis, which was a cheap one, would be much dearer than the existing method. He thought that the author could not have sufficiently considered the cost of providing electricity at the stations up and down the line. In regard to the switches, he should be glad to know how Mr. Timmis got over the difficulty, not of breaking the contact, but of making the contact again perpetually, because it had been found that sparkless switches, even as low as 5 amperes, when constantly used, suffered a great deal, and required constant attention. As to the long pull magnet, there were many modes of obtaining the same result, but the use of the counterweights, as mentioned by Mr. Timmis, involved a great waste of power. It was no doubt a useful locking arrangement, but it was not as good as it might be.

Mr. S. P. Walker desired to endorse the remarks of Mr. Crompton with regard to the great skill shown by Mr. Timmis in working out his method. Engineers connected with the working of railways would of course welcome anything that would increase the safety of life and goods, and he hoped, therefore, that there was a great future for some system of electrical signaling. He had often wondered that electricity had not been before applied to the working of railway signals. There were, however, one or two points on which he thought that Mr. Timmis had not done electricity full justice. In the form of the magnet that he had brought forward he had attacked the question at the wrong point. Nothing could be better than his mechanical arrangement for the locking of the signal, should anything happen to the electrical part of the apparatus; but he had placed some unnecessary difficulties in the way. He had stated that up to the present time it was impossibe to get more than a ½-inch pull; but he would ask him to go to the nearest dynamo machine with a piece of iron in his hand, and see at what distance it would pull it away; it would certainly be considerably more than half an inch. Mr. Timmis had also stated that the pull might be increased by leverage, but that it became too expensive, because the current was excessive and the impact too great. That, he thought was not so. From the author's figures it appeared that 8 lbs. pull was obtained at 3 inches distance. By a well-known law the pull between a magnet and its armature varied inversely as the square of the distance, therefore at half an inch distance he would get 400 lbs. On the ordinary principle of the lever, taking a lever 7 to 1, and using it at half an inch, he would only require about 56 lbs. The meaning of that was that he could use a magnet, taking the same current, one-eighth of the size of that

which he had exhibited, if he would use some simple form of multiplying gear, and that would reduce the maintenance very considerably. They might do anything they liked if only the magnet was big enough, and constructed so that the lines of force would reach the armature. Mr. Timmis was mistaken with regard to the action of the solenoid magnet. That action was simply that each coil of wire around the bobbin exerted its own pull upon the core, and as the core gradually drew into the bobbin, more and more of the wire came into action. He was mistaken in supposing that all that he had done could not be effected with the solenoid magnet. No doubt it was more expensive, because the whole pull was not got at once, but there was a gradual pull. They could not have both, and something must be sacrificed. The author might have got all that he wanted without going out of his way to invent a new magnet. As to the impact, he thought it was a rather heavy one. He saw no necessity for an impact following on the magnet at all. It would be easy to place some buffer to receive it if necessary. The construction of the magnet was very old. He remembered, eight or nine years ago, a very similar form being brought before the Society of Telegraph Engineers by Mr. Falconer, of Manchester, who was under the impression that electricians were wasting all their power. The matter was taken up by the then president of the society, and it was fouud that Mr. Falconer was correct, so far as pull went, but there was one peculiar feature about his method—though it would attract in great force it lost its power at very small distances from the pulls. What was good in the author's method, so far as the long pull was concerned, was due to the old solenoid magnet, and what was good with regard to holding power was due to Mr. Falconer's system. He disputed the economy of Mr. Timmis's method. He had given a working current of 5 amperes, and the resistance of the circuit was given as five ohms. By the well-known law that the work done was equal to the square of the current multiplied by the resistance of the circuit, he made out the result as 125 watts, or, roughly, about one-sixth horse-power. Taking the pull at 90 lbs. per second, and two seconds for a pull, as stated by the author, that would give a pull of 180 foot pounds. For that expenditure of energy they only had a force back in the magnet of 2½ foot pounds, and he hardly thought that that confirmed the author's statement with regard to economy. As to railway points, they had 1¼ horse-power to pull a railway point over. The whole thing might, he thought, be carried out at a much less expense than Mr. Timmis had foreshadowed by his arrangements. He was using too large currents, and he would suggest that instead of using 5 or 10 amperes, he might bring it down to one-tenth or one-twentieth of an ampere, particularly if he was going to work with secondary batteries. The great difficulty in connection with primary batteries was that when they were furnishing large currents electrolysis went on so fast that secondary cells were formed which required frequent attention. So long as they were furnishing small currents they had no difficulty in getting a battery that would last a long time. In providing an increased number of batteries, there was, of course, an increased consumption of material because of the increased number of cells, but the consumption was so much lessened in each cell, that there was an enormous gain. Mr. Timmis had perhaps fallen into the mistake of thinking that they were not able to get more than half an inch pull by the fact that they rarely saw an electro magnet that was constructed to pull half an inch. No one would construct such a magnet, except for some special reason, because he would know the great advantage of having the armature close to the magnet. He quite endorsed what Mr. Crompton said with regard to the trouble experienced with switches and contacts. There was nothing more troublesome than keeping surfaces clean through which electric currents had to pass, and the larger the current the greater the difficulty. Mr. Timmis was also mistaken in supposing that with a primary battery it was impossible to insert resistances as with a secondary battery. He could throw in his resistances or cut off the number of cells, adopting whatever plan was most convenient. Whatever he could do with a secondary battery, he could do equally well with a primary battery. He also endorsed what Mr.

Crompton had said as to the difficulty of providing power.

Mr. Davey asked what was the number of cells in the primary battery required to work the apparatus exhibited. It appeared to be very large.

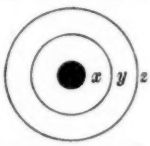
Mr. Timmis, in reply, said that the number of cells appeared to be very large to work one signal, but the cells required for that purpose would work equally well for a score of signals. Mr. Currie and himself had no doubt, not from theory, but from absolute practice, that they could work wherever they liked with secondary batteries, and also with primary batteries, if the conditions were favorable. At Swansea they had fitted up one signal, and before long there would be a great number there working from one, or, at most, from two, batteries which were being regularly charged every six weeks, without any difficulty at all, from dynamos which were used for lighting purposes. There were engines running at many big stations which could occasionally be utilized for an hour or two to run a current from a dynamo, or to recharge the batteries as they were running down. That did not appear to him to be a very extravagant arrangement for the transmission of power. Where there were not those conveniences it was proposed to use the Lalande oxide or copper battery. As to the use of a minimum or maximum current, he maintained that the current he was using was an intermittent one. He was certain that the Lalande oxide or copper battery would not want touching oftener than six weeks, and he believed not oftener than once in three months. The weight of a primary battery was not considerable. The cells were being made by M. Lalande so light that a whole battery for a fair-sized junction would not weigh more than 1 or 2 cwt. Mr. Walker was wrong in supposing that the same results could be obtained with a solenoid magnet as with a Currie magnet. It would be seen from his figures that the ½-inch pull was 70 lbs., and not 400 lbs., as Mr. Walker had stated. The absolute weight of the counterweight was nothing like sufficient to regulate the pull in the way in which it was done by his method. Mr. Currie and himself were perfectly well aware of what Mr. Falconer had done with his magnets, and also with what Mr. Holroyd Smith and other inventors had done.

THE SOLAR TEMPERATURE QUESTION.

By F. GILMAN.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

PROF. WOOD, in the November number of this Magazine, calls for the proof of the statement that the intensity of heat emitted by a spherical incandescent body varies inversely as the square of the distance from its center. I have referred him to Captain Ericsson's experimental demonstration, but if he prefers a theoretical one it is very easily given.



Let x represent an incandescent spherical body, and suppose it to be maintained by any cause at the same temperature. After a time the flow of heat from the body will be uniform, and each point of the surrounding space will also acquire a constant temperature. This represents very nearly the state of affairs in the solar system, as regards the distribution of heat. For the temperature of the sun is nearly constant, and the average temperature of the earth's surface has not sensibly changed for a long period of time. This being premised, let y and z represent two spherical shells concentric with x, and suppose them to be very thin and perfectly diathermanous. Since the flow of heat from x is uniform, the amount that passes through the shell y, in a given time, must be equal to the

amount passing through z. For if more, or less heat, passes through y, than passes through z in the same time, the difference must be imparted to, or withdrawn from the space between the two shells; and any body placed in this space would be constantly growing hotter or colder. But this is contrary to the observed facts.

Let the amount of heat which passes through the shell y in a unit of time, as well as that which passes through z, be denoted by C. Let A represent the area of y, and B the area of z. Then the intensity of the heat passing through y will be given by $\frac{C}{A}$, and the intensity of the heat passing through z by $\frac{C}{B}$. But these quantities are to each other inversely as the squares of the distances of the respective shells from the center of the heated body x. Such is the law of the distribution of radiant heat as we advance from the surface of an incandescent spherical body outwards; but it is of course no longer applicable when we advance from the surface inwards, since we have here to do with conduction, and not radiation.

I do not see why the law of Dulong and Petit is entirely at variance with that of the inverse squares, as Prof. Wood affirms. They appear to me to be quite independent of each other. The law of Dulong and Petit gives the quantity of heat radiated in a unit of time by a body whose temperature is not more than 200° C. above that of the surrounding space. The law of inverse squares, however, as applied to a hot spherical body, does not enable us to determine how much heat the body will radiate when at a given temperature, but it shows that whatever heat is radiated will be so distributed in the surrounding space, that its intensity will be inversely as the square of the distance from the center of the body.

The medium to which I referred in my former article was the sun's atmosphere which I suppose is not diathermanous.

Photometry affords a means of verifying the law of inverse squares as applied to light.

Assuming the intensity of the sun's light at the surface of the moon to be the same as it is at the earth, if all the light incident upon the moon were reflected, the intensity of the moon's light at the earth would, according to the law of inverse squares, be about one-fifty-thousandth of the intensity of sun-light. According to the observations of Sir William Thomson the intensity of the light of full moon is one-seventy-thousandth of the intensity of the sun's light. But inasmuch as he gives this only as a very rough approximation, and since not all of the light incident on the moon is reflected, it must be acknowledged that the agreement between the theoretical and the observed intensity is as close as could be expected.

THE SCIENCE AND PRACTICE OF ENGINEERING.*

By Prof. KENNEDY, University College, London.

From "The Engineer."

Professor Kennedy said he was very glad to have an opportunity of putting before younger engineers some of the ideas which ten years' experience in combined academical and professional work had brought specially to the front in his own mind. He was rather assuming that those who heard him were engineers, or directly interested in engineering matters, and he would make no apology for being somewhat technical. The subject he had chosen was brought into prominence by his special work, and he hoped it was not too well worn to be worth a little consideration. The views held upon it were exceedingly divergent; so divergent, indeed, that it was hardly to be doubted that the true view must lie between the extremes. They must endeavor to find where. On the one hand, there was the man who prided himself on being practical, who would barely hear it said that there was any science of engineering, and who would condemn

* An address delivered on the inauguration of the Crewe Scientific Society.

beforehand any propositions or schemes in the devising of which he imagined that scientific method, or, worst of all, mathematical calculation, had been employed. On the other hand, the man of science, pure and simple, and especially the mathematician, was prone to find out that because so much engineering work could be done, or at any rate was done, without calculation—and in particular because so few engineers were really able to solve, or even to comprehend, mathematical problems, which to him were quite simple, engineers were mere empirics, that no science worthy of the name existed in engineering, and that engineers could only be considered scientific men by a stretch of courtesy. It was right to say that such extreme opinions were not held by first-rate men, either as engineers or men of science. But fourth-rate men were much more free of their opinions, much more dogmatic, more positive that they only had the truth—in engineering as in other matters—than those of the higher ranks. In what he had to say they would understand him to be using the much-abused word "scientific" in the very widest possible sense. Let "science," if they liked, include all the exact knowledge, and let "scientific" mean the method of arranging, comparing, reasoning on, and applying such knowledge. Moreover, it did not follow that if they did a thing that had been done by some scientific forerunner, they, too, were necessarily scientific. Whether it be scraping up a slide face, or drawing a stress diagram, the work might be scientific or unscientific, according to the spirit and method in which it was done. In both cases the methods of procedure had been invented for them. They had not anything original to do, anything novel in the way of scraping or of girder stress diagrams. If they did either just as and because they had been told to do it in a particular way, without knowing or caring anything as to the why or wherefore, their work was no more scientific in the one case than in the other. But in both cases equally the work might surely be thought scientific if it was carried out with a knowledge of the meaning of what was done. Of why, for instance, scraping in this case was to be preferred to planing, of why it was an improvement on the old grinding process, of why the scraper was not ground like a cutting tool, and so forth. Not, of course, that these should be leading ideas in one's mind at the time, when one's only idea should be to make the surface as true as possible, but that they should be only absent because they were laid up in a corner of one's brain, duly labeled, and capable of being brought down to explain themselves whenever called for. He mentioned as examples of engineering work more or less familiar to them the two very different things, scraping a surface and drawing a stress diagram. He chose them because the latter belonged to the class of work frequently called scientific, when the former was called mechanical. To this he objected. On the whole, the drawing of the diagram was much the easier of the two things. It was just as easy, moreover, to do it unscientifically, or, as one might say, by Molesworth. One was bound to say that the actual problems with which a workman was daily brought face to face were, in not a few cases, more complex and difficult than those to which the name of scientific was sometimes alone given. Thus, no engineer need be a mere tradesman or handicraftsman. In every grade, in every branch of their work they handled materials and carried out operations which gave them plenty of food for thought, and plenty of opportunity for scientific method. They had the proud distinction of belonging to the profession which, of all others, was *par excellence* scientific. And no profession of the delights of ignorance on the part of unworthy members of it could alter what appeared to be the plain facts of the case. He was sometimes amused with the zeal with which an enthusiastic physicist would proceed to throw all their mechanical units to the winds, and to improve upon all the ideas of engineers by expressing them in terms which were unintelligible except to a very select few. He had occasionally come down heavily upon such improvers of mechanics by suggesting that for every mechanical calculation they had to make outside an examination paper, engineers had to make twenty. So it was hardly fair to improve mechanics out of sight of the few people who definitely and positively knew it and use it in their every-

day life. But to come now more to particulars, and deal with things that were more present to their minds than some of these general considerations, let them work their way to the definite question of engineering calculations. How far and how often could an engineer arrive at definitely valuable results by calculation? To what extent could calculated results be taken to represent actual facts, and trusted in design and construction? These questions concerned all of them in different degrees, and on their answer to them depended to a great extent their method of work. It happened to be his good fortune to be at the head of a laboratory where they had special facilities for making inquiries into this very matter, directly and indirectly. He was, therefore, all the more ready to take that opportunity to speak about it. In the first place, he said that an engineer could never expect to arrive at valuable or trustworthy results by means of calculations taken from books, calculations which he did not understand, "rules," so called, from pocket-books, &c. Pocket-books, &c., were all very well to remind them of former facts which they forgot or did not carry in mind, and to give by tables the results of long arithmetical calculations. This was their legitimate and very important function. But, directly it came to taking up a formula which one did not understand, a's and b's and c's, putting in values and calculating results merely by rule of thumb—as far as one's self is concerned, the result was worth absolutely nothing, and few, if any, sensible men would trust such a result. In his mind that definitely put an end to the idea of certain mechanical engineers about universal engineering dimensions all ready calculated. There was plenty of engineering work to be done without actual formulæ—the object of so much dread and scorn—done well, and done scientifically. From his point of view it was a great advantage to a man if he could follow the reasoning, physical or mathematical, on which other parts of engineering work, and especially design, depended. Fortunately for most of them, there was for the most part no necessity that a man should be a great mathematician in order to be a fairly competent engineer. He had, or had had, the pleasure of knowing personally some of the greatest mathematicians of our time. With one exception not one of them would make his mark as an engineer, even if he confined himself to the scientific side of his work. He had also the pleasure of knowing some of our greatest, most original, and longest-headed engineers, and, so far as his knowledge went, hardly one of them had such aptitude for mathematics as would place him in even the second or third rank of matbematicians if he devoted himself to that most fascinating subject, But all the same there were engineers in plenty—not, certainly, as many as could be wished—who had succeeding in grasping thoroughly the science, mathematical and physical, of their profession without having lost the peculiar bent of mind which specially adapted them to be engineers. And into this class they doubtless wished to enter so far as circumstances allowed. The late Professor Rankine long ago pointed out that the so-called discrepancies between "theory" and "practice," between results theoretically best and those practically best, did not exist, could not exist, if only the theory were right. He feared they got into rather a slovenly way of talking on this subject sometimes. They said that a certain system of levers should theoretically enable them to lift 1,000 lbs. with 10 lbs. pressure, but that practically it only enabled them to lift 500 lbs. This simply meant that the theory was wrong, or at least incomplete. A complete theory would take into account all the friction at all the joints, giving to each its proper coefficient; all the variations from accuracy in the length of the levers, and so on. But if one chose to take theory on an ideal combination of frictionless rods, and apply it to an actual combination of frictional ones, of course the results would show a discrepancy. This reason was not to be sought in any fault in the theory, but in themselves, for expecting it to apply to a set of conditions for which it was by no means adapted. It happened in many cases that their engineering problems were terribly complex, both mathematically and physically; even to state them in any exact form was very difficult. So they contented themselves with an approximate representation of them by some theory or formula. The science of an engineer was not only

shown by his knowledge of the best working theory formulated or unformulated—very often the latter—but by the accuracy of his estimation of the extent to which his theory probably represented the actual case, of the extent to which he might trust his assumptions, and of the points in which the actual results would probably differ most from those given by the approximate theory. He had used the expression "unformulated theory." He had known men—he dared say they all had—who had wonderful physical insight, with very little mathematical knowledge. The exact process of reasoning by which they arrived at their results they had difficulty in putting into words, probably for want of familiarity with scientific terminology. But they had wonderfully accurate and correct notions as to where a given piece of machinery would give way, how best it ought to be strengthened, and so on. Of course such kind of knowledge was dangerous, because it was mainly based upon experience, and that within a certain limited range. It was, therefore, apt to give extraordinary results when applied outside that range. In itself it was to be respected, and within certain limits trusted. But the man possessed of this talent ought, if he had a right knowledge of himself, to be the first to mistrust his own judgment applied to matters beyond the range of his own experience. Then must step in some one who could give reason for the faith that was in him, who was capable of tackling a new problem, of seeing through it, and getting at its real meaning. But even here, results did not always presuppose actual formulæ. He rather insisted on this idea, because he would not like them to think that they were altogether shut out from the scientific side of their work by being bad mathematicians. Within certain limits, no doubt, the better capacity one had for mathematical reasoning, the better would one be able to work at the science of engineering. But he should like them to believe that a little mathematics, if only it be sound and accurate as far as it went, might go a long way. Also, that much mathematics misapplied might go only too short a way. He would now ask them to look at the different sets of considerations which go to determine the dimensions of an engineering structure or machine, and see how far they were subjects for calculation; and then he would say a few words about the calculations themselves. (I.) One set of considerations which they had to keep in mind was the architectural or æsthetic considerations. These considerations referred to form generally, and were very important. What was the criterion of beauty in engineering affairs? Or was it necessary to have one? He was not competent to lecture on art, and however enthusiastic he might be on the subject outside his profession he did not think that art took a very important place in engineering as generally understood. But at least in structural engineering the point of view occurred often enough to be pretty important. As to machines, he thought most of them would be disposed to use the word ugly to describe anything ill-proportioned; and they would consider a thing ill-proportioned if its different parts were unequal in strength or in wearing resistance; if, in fact, its metal was put in the wrong place. Sometimes metal had to be used for its own sake for weight and mass only, but that was seldom. As a general rule, uniformity of strength throughout the whole machine, absence of superfluous material everywhere, was the thing to be aimed at; and obvious departure from this rule was always ugly. In the case of structures, also, he believed that the true beauty of an engineering structure was to be found in the fitness of each of its parts to do its own particular work. He really believed that in time, as one learned to judge of engineering structures by proper standards, they would come to think those structures the most beautiful which were designed and proportioned from an engineering point of view. Recently he had an opportunity of seeing the large suspension bridge between New York and Brooklyn, and it appeared to him that it was singularly graceful, indeed handsome in a way that such structures seldom could be. In regard to cast-iron columns for rooms, it was quite a mistake to attempt too much ornamentation. He believed that surface decoration would be much more effective than mouldings. (II.) The next set of considerations determining the dimensions of structures and machines were

considerations of duration—of resistance to wear. He supposed that none of them had gone further into this matter than to gather from their own experience and other people's certain constants. But if they wanted to know how little they really knew about that matter let them look up Mr. Towers' experiments and see how an axle floats in oil and causes actual fluid pressure there at its center of nearly double the nominal pressure. Much interesting work remained to be done here, and the results were of that pleasing kind which had a direct relation to practical work as well as a high value in pure science. (III.) Now he came, lastly, to the principal set of considerations, viz., considerations of strength. Here calculation and the application for exact scientific formulæ and reasoning came in frequently. Here, therefore, of all places, it behoved them to know what they were doing in applying formulæ—for here, of all places, might a misapplication of calculations have disastrous results. Much trouble would be spared if engineers always kept in view that their results could not possibly be more accurate than their data. Now, their data were ordinarily conditioned by three things: (1) The accuracy with which the forces causing stress is known. (2) The accuracy with which the stress caused by the forces is known. (3) The accuracy with which the resistance of materials to stress is known. The engineer had first to see that he thoroughly understood his own problem—that he knows what question he has to ask, why he has to ask it, and what data he has to go upon. He had then carefully to examine his data, and to make up his mind as to how far they are certain, and how far the maximum forces are known. Next, he had to find some representative problem which can be put into a simple form, and which shall be as near as possible to the problem he wants, actual problems, taken in their completeness, being in almost every case too complex to deal with. Then he had to get his data put in the representative problem, and work out an answer. Lastly, he had to remember that the answer is to the representative, not to the actual problem; and he had to exercise his own judgment as to its application. But their society was called a scientific, not an engineering, society. He had been taking for granted, as he supposed he might fairly do, that practically they were all engineers, and that it was an engineering science that they had chiefly to do with. This, however, he hoped, was not altogether the case. But even if the science of engineering in its various aspects was the only one which they proposed to discuss in their society, he hoped they would individually give more or less attention to the other branches, especially those of natural science. An engineer was a man more or less trained to habits of accurate observation, more or less compelled to look into and around things that presented themselves to him. It was the very frame of mind for any science, not only that of their profession. For himself, he confessed he thought the principle a good one to know all about something and something about everything. Nothing increased one's enjoyment in life, made life so much worth living, as the gathering in of knowledge of all kinds about the world we live in, and the educating one's self to appreciate and understand it, and all the beauties it contains. And not only the physical world, but the world of men, the writers and thinkers, the musicians, the painters, the poets, the architects of the past and of the present. Their profession, with all its fascinations and interest—in enthusiasm about which he himself would yield to no one—was essentially in the aspect most familiar to them a modern one. But they themselves were not modern. He urged them not to allow their profession to separate them from the ancient universe all around, nor to work and learn as if no one had worked and learnt before them, or as if their little specialty were the great domain of nature itself. Let them try and keep touch with nature, and with their fellow men, and not only with nature and the men of to-day, but with those of all time. The more they tried to know, the more they knew how little they knew. In one's own profession one might know much, perhaps be only too conscious of that fact. But let them listen to the musician, hear what the violins say, "riding the stormy symphony in royal orchestras," or tenderly telling of all that is beautiful in the lovely quartett. Where had they got the

ideas that were to be put alongside these, where in their sphere could they turn for similar means of helping, encouraging, ennobling others? Or, let them see how the poet weaves out of his own brain the thoughts that somehow seem to have been made especially for us too, who lived centuries after him; how he not only sums up our wishes, our desires, our aspirations, but in doing so raises them and us together into higher regions than they would otherwise have ever entered. Or, to come back once more to what folk called science, let them take a country walk with anyone who knew the flowers, the stones, the rocks, the trees, the insects, all the pictures that nature ever put before us, and see how desperately ignorant they would find themselves if they had not looked at those subjects. They would see how one man could live in the same universe with another, seeing the same things and yet knowing nothing about them, in fact seeing them not at all. He did not speak as a biologist or a geologist, he only knew enough of those things to know how fascinating they are, how much one may long to know more. But he knew even a small knowledge of them added to one's interest in life. Everything one sees or touches was full of life and interest. and yet more and more full of interest as one got to know more and more about it, and one saw how great everything is, and how wonderful, and how beautiful and how no work in nature was scamped, but was as exquisite in its minuted microscopic detail as it was grand in its mountain outlines. And one learned, or one tried to learn. how little one is one's self; how insignificant as compared with the vastness of nature, how ugly, sometimes, as compared with the beauty of nature. One got peeps into a world grander than the Alps that some of them loved, more beautiful than fairyland. One was awed into modesty and sobriety of opinion. One was constrained to try to make one's work worthy of its place in the universe, worthy to follow on the good that had gone before, worthy to be looked upon by our successors as something which, being the fittest, had survived to them. And perhaps after the end there might be spoken of them in some small measure the noble words of Marcus Aurelius, which had recently been applied to that greatest of men of science, greatest of Englishmen, he would say—Charles Darwin—words which perhaps expressed the character of an ideal man of science: "Remember his constancy in every act which was conformable to reason, and his evenness in all things, and his piety, and his serenity of countenance, and his sweetness, and his disregard of empty fame, and his efforts to understand things; how he would never allow anything to pass, but carefully examined and clearly understood it, how he bore to be blamed unjustly without blaming others in return, how he did nothing in a hurry, how he was not given to reproach people, how firm he was in friendship, how tolerant he was in freedom of speech, how religious he was without superstition; and how it were to be wished, when the last hour comes, to die as he died."

MEASUREMENT AND FLOW OF WATER IN DITCHES.

By AUG. J. BOWIE, Jr.

A Paper read before the Technical Society of the Pacific Coast.

In California, where the rainfall over large portions of the State is small and periods of drought of not uncommon occurrence, the development of the agricultural as well as the mining interests, necessarily resulting from the continued influx of population, will be dependent greatly upon the careful husbanding of the water supply. The sources of this supply are comparatively limited, and the problem of systematic irrigation will grow daily in importance from the necessities of the farmers; and the demand for water will steadily increase with the more extended cultivation of the soil.

The costs of construction and maintenance of the necessary canals and ditches (depending principally on their capacity)

will be of prime importance to the owners, who will appreciate fully the value of a correct determination of the flow of water. The easy-going farmer who purchases the water, will ultimately discover the necessity of knowing how much he is receiving, and then will come the demand for a standard of measurement of water.

The history of northern Italy, from the fourteenth to the eighteenth century, is replete with accounts of disputes and difficulties arising from the non-existence of some accepted standard of measurement of water. Similar troubles have arisen at times in the mining regions of this country, as can be attested by numerous court reports.

With the experience of the past, and in consideration of the future interests of the country, it would seem advisable that some uniform gauge and standard of measurement of water should be adopted.

The miner's inch has only led to confusion and is the relict of the Mexican and Spaniard, who possibly took it from the Italian. Like the Italian *oncia*, which varied in nearly every province, so its brother the miner's inch has followed suit to even varying in the same district.

In the construction of the various water-supply systems for the different placer regions in this State, certain experience in the measurement and flow of water has been acquired, and it has been considered of sufficient import to place some of the results of this work on record, with a view of assisting in clearing up the confusion about the *Miner's Inch*, and giving to those interested in the profession the benefits derived from the several works.

The Miner's Inch.—The Miner's Inch of water is a quantity which varies in almost every district in the State; no one gauge has been uniformly adopted, nor has any established pressure been agreed on, under which the water shall be measured. In some counties there are 10, 11 or 12-hour inches, and in others there is a 24-hour inch. The apertures through which the water is measured are generally rectangular, but vary greatly in width and length, being from 1 inch to 12 inches wide and from a few inches to several feet long. The discharges are through 1′, 1½′, 2′, and 3-inch planks, with square or with square and chamfered edges, combined or not, as the case may be. The bottoms of the openings are sometimes flush with the bottoms of the boxes, sometimes raised above them. The head may denote the distance above the center of the aperture, or again that above the top, and varies from 4½ inches to 12 inches above the center of the aperture.

The Smartsville inch is calculated from a discharge through a four-inch orifice with a seven-inch board top; that is to say, the head is seven inches above the opening, or nine inches above the center. The bottom of the aperture is on a level with the bottom of the box, and the board which regulates the pressure is a plank one inch thick and seven inches deep. Thus, an opening 250 inches long and four inches wide, with a pressure of seven inches above the top of the orifice, will discharge 1000 Smartsville miner's inches. Each square inch of the opening will discharge 1.76 cubic feet per minute, which approximates the discharge per inch of a two-inch orifice through a three-inch plank with a head of nine inches above the center of the opening, the said discharge being 1.78 cubic feet per minute. The Smartsville miner's inch will discharge 2534.40 cubic feet in twenty-four hours, though in that district the inch is only reckoned for eleven hours.

Other Inches.—The miner's inch of the Park Canal and Mining Company, El Dorado County, discharges 1.39* cubic feet of water per minute. The inch of the South Yuba Canal Company is computed from a discharge through a two-inch aperture, over a one and one-half inch plank, with a head of six inches above the center of the orifice.

At the North Bloomfield, Milton and La Grange mines, the inch has been calculated from a discharge through an opening fifty inches long and two inches wide, through a three-inch plank (outer inch chamfered), with the water several inches above the center of the opening.

Determination of the inch experiments at Columbia Hill.—To determine the value of this miner's inch, a series of experiments was made at Columbia Hill, latitude 39 N., elevation 2900 feet above the sea level. The *module* used was a rectangular slit fifty inches long and two inches wide; head seven inches above the center of the opening. The discharge was over a three inch plank; the outer inch chamfered.

* Estimated by J. J. Crawford, M.E.

The size of the opening was taken with a measure (micrometer attached), which had been compared with and adjusted to a standard United States Yard. Time was read to one-fifth of a second; the level of the water (drawn from a large reservoir) was determined with Boyden's hook, micrometer adjustment. The following results were obtained:

One Miner's Inch will discharge in one second....	.026	cub. ft.
One Miner's Inch will discharge in one minute...	1.57	"
One Miner's Inch will discharge in one hour.....	94.2	"
One Miner's Inch will discharge in 24 hours.....	2260.8	"

The coefficient of efflux is 61.6 %. These figures are within the limits of $\frac{1}{500}$ possible error.*

As the two-inch aperture requires too much space for gauging large quantities of water, custom has changed the form of the module, and an aperture twelve inches high by twelve and three-quarter inches wide, through a one and one-half inch plank, with a head of six inches above the top of the discharge, is now used. These openings discharge what is accepted as 200 miner's inches.

A series of experiments was made at La Grange, Stanislaus County, California, latitude 37° 41′ N., elevation 216 feet above the level of the sea, to determine the value of the inch thus delivered in the claims. The results here given are the mean of a series of gaugings taken from nine different apertures, discharging in the aggregate 1,800 miner's inches.

The water was drawn directly from a flume and discharged into a small reservoir, across the lower end of which was fitted a gauge. The velocity of the water issuing from the flume was broken by several drops as it entered the reservoir, and the gauge at the lower end was raised sufficiently to prevent any flow due to an increased velocity which might have been required in the flume.

The level of the water was determined with a Boyden's hook.

The discharge from the module was caught in a flume and conducted to a box fitted and leveled for the purpose. Time was read to one-fifth of a second. The following results were obtained:

	Cubic Feet.
1 Miner's Inch discharged in 1 sec..	.02499
1 " " " 1 min..	1.4994
1 " " " 1 hour.	89.9640
1 " " " 24 hrs.	2159.1460

Effective coefficient of efflux, 59.05 %.*

An experiment on a single aperture of this form, made by Hamilton Smith, Jr., gave a discharge of 2179.4 cubic feet per miner's inch in twenty-four hours. The 2230 cubic feet of the North Bloomfield inch can only be considered an assumed rough estimate of discharge in 24 hours for 1 miner's inch.

The theoretical velocity in feet per second, of a fluid flowing into the air, through openings in the bottoms or sides of a vessel or reservoir, the surface level of which is kept constantly at the same height, is equal to that which a heavy body would acquire in falling through a space equal to the depth of the opening below the surface of the fluid, and is expressed as follows:

$$v=\sqrt{2gh}.$$

In which v = velocity in feet per second.

g = the acceleration of gravity.

h = the height fallen in feet.

This is called Torricelli's theorem, which supposes indefinitely small orifices with thin sides, and assumes that the upper surface of the water and the orifices are under the same conditions as regards atmospheric pressure. Conditions and size of sectional area of the aperture, friction resistance of the air to motion and pressure of the atmosphere are all neglected.

The value of g varies in different latitudes, but for all practical purposes is taken as equal to 32.2.

$$\text{The theoretical head} = \frac{v^2}{2g}$$

The acceleration of gravity at latitude 45° = 32.17 feet per second, being represented by g, for any other latitude, l.

$$g'=g\ (1-0.\ 002588\ \cos.\ 2l)\ \dagger$$

If g represents the acceleration of gravity at the height, h and r the radius of the earth, the acceleration of gravity at the level of the sea equals—

$$g'=g\left(1+\frac{5h}{4r}\right)$$

* The experiments were made in 1874, by H. Smith, Jr., C. E.

* The experiments were made by the author.

† See professional papers, Corps of Engineers, U.S.A., No. 12, page 26.

Flow of water in open channels.—There is no generally accepted formula for determining the velocity of water in open channels. The tables based on theold formulas published prior to the works of D'Arcy and Bazin, in France, and of Humphreys and Abbot, in the United States, being founded on a data which ignore the important factor of the nature of the bed and the sides of the channel, have proved unsatisfactory. Hydraulic engineers have been compelled to rely for correctness of calculated result on the application of a combination of a few known laws with experimental data, which latter, though all important, have been too restricted for the deduction of reliable mathematical theory.

The formulas, in terms of dimensions of cross section and slope, are based upon the supposition of either "permanent" or "uniform" motion. Permanent motion approaches the condition of streams, permits changes of cross section and slope of the water surface, excepting sudden bends, causing eddies and undulations, but demands that the discharge from the different sections should be identical. Uniform motion, in addition, requires an invariable cross section and constant slope of the fluid-surface. The general formulas based on permanent motion, differ from those restricted to uniform motion, "by taking into account changes of living force produced by changes of cross section at the different points."* If these variations are unknown, the difference between the formulas disappears.

Chezy considered that the resistances encountered by water in uniform motion were in direct proportion to the length of the wetted perimeter, to the length of the channel and to the square of the mean velocity, from which he deduced the formula.

$$v = c\sqrt{rs}.$$

v is the mean velocity in ft. per second.
c a coefficient taken at a constant value.
r the mean hydraulic radius in feet.
s the fall of surface in a unit of length.

The equation indicates the relation of the mean velocity to the slope and the mean hydraulic radius. The value of the coefficint c has been demonstrated empirically to have a wide range. This formula, however, has been considered the simplest, and has been used by many engineers, different values being given to c, varying from 84 to 100 for large streams, and being as low as 68 for small streams. "Though there is abundant evidence," says Higham (p. 5), "that the latter is much too high for low values of v in earthen channels, and that 100 is too low for very large rivers, as high a value as 254.4 having being deduced from the Mississippi observations."

D'Arcy and Bazin, by their experiments on channels of moderate section with limited variation of grades, proved that the coefficient c involved not only r and s, but also a constant for the different degrees of roughness of the channel, the formula being applicable within certain limits of inclination and values of r.

Humphreys and Abbot make the velocity vary with the fourth root of the inclination, while Hagen assumes the velocity to vary with the sixth root.

Ganguillet and Kutter considered that the Chezy formula, $v = c\sqrt{rs}$. was the correct point of departure, but that the coefficient should be made variable, involving not only r and s, but likewise the degree of roughness, in the bed or channel.

Ditches in California.—In the mining districts of California, ditches are constructed boldly with steep grades and on irregular lines with numerous sharp curves. The cross sections, originally uniform, become more or less varied. Absorption, percolation, evaporation and leakage, reduce the flow. A distinct reliable factor for each of these sources of loss cannot well be incorporated in the coefficient of discharge. If, then, it is intended to cover all of these common sources of loss by such a coefficient, its value must be a material modification of values given commonly in the text books. It would be certainly an affectation of accuracy to apply so complicated a formula as that of Kutter in such a case, since the modifying conditions which can be estimated but roughly, call for a large reduction of the calculated result. This will be apparent from the measurements of discharge given further on. The simple formula, $Q = ac\sqrt{rs}$, expresses more fitly the result of experience in such cases, wherein—

Q—Is the quantity of water which the

* Humphreys and Abbot, Mississippi Report, p. 207.

ditch is capable of carrying in cubic feet per second.

a—The effective area of cross section of ditch as constructed originally, in square feet.

r—The hydraulic mean depth in feet.

s—The fall of surface in a unit of length.

c—A coefficient† covering all common losses.

Examples of value of coefficient in Ditches.—In its application to the North Bloomfield Main Ditch,* (length 40 miles, sectional area 23.89 square feet, grade 16 feet per mile) with its abrupt turns and sinuous course, the value of the coefficient *c*, as determined, varies from 44.7 to 37.7 in accordance with the season of the year.

The Texas Creek† branch ditch is about seven-tenths of a mile long. Its sectional area is 13.5 feet and the grade is 20 feet per mile. The sides are rough and the curves are sharp. With a flow of 32.8 cubic feet per second, the ditch runs about full. The value of $c=33$. In connection with this ditch there is a rectangular flume 2.67′ wide × 2.83′ deep, made of unplaned boards, set on a grade of 32 feet per mile. The flume has some sharp but regular curves, and the water from the ditch runs it nearly full at these points. With the discharge 32.8 cubic feet per second, $c=59$.

On the Milton line, from Milton to Eureka, a distance of 19.4 miles, the sectional area of the ditch is 20.39 square feet, grade 19.2 feet per mile for the earthwork and 32 feet per mile for the flume. The line is very irregular, having many drops and chutes. The distance from Milton to the measuring box at Bloody Run is 29½ miles. The minimum established grade for the last 10.1 miles was 16 feet per mile, with a sectional area for a ditch of 23.05 square feet. The coefficient *c* determined from the gauging at the measuring box has varied from 22 in its leakiest condition to 31, which latter can be taken as correct for the present condition. In the succeeding 30 miles below the gauge, owing to a better character of ground, the coefficient reaches 41.

The La Grange main ditch, 17 miles long, has a sectional area of 22.5 square feet, and a slope of 7 feet per mile. From the delivery at its Patricksville junction the coefficient *c* is determined to be 52, but it is based upon the assumption that the depth of the canal is three feet, whereas in the original construction it was supposed to have been made four feet deep, the discharge, therefore, due to such a sectional area, would diminish necessarily the ascribed value of *c**.

In all these canals, after the artificial banks are well consolidated, the water area is increased beyond the original excavation in the natural ground.

Accuracy cannot be expected in calculating the values of Q for proposed ditches of such character. Important losses must vary in every ditch, depending on the nature of the ground, and the character of the construction of the work and the season of the year. The feeders along the lines compensate largely for these losses. In order to be safe in estimating the capacity of a ditch, the value of the coefficient *c* for the dry season should be taken.

The following facts show the magnitude of the losses due to absorption, leakage, evaporation, etc.:

Three thousand miner's inches of water (a flow of 75 cubic feet per second) turned in during the dry season at the head of Bloomfield ditch, will deliver 2700 inches (67.5 cubic feet per second) at the gauge 40 miles distant. Twenty-four hundred inches of water (60 cubic feet per second) turned in at the head of the Milton ditch delivered formerly at the gauge, 29½ miles distant, 1450 to 1600 inches (36.25 to 40 cubic feet per second), but at present 2500 inches (62.5 cubic feet per second) turned into the head of the ditch, deliver 2000 inches (50 cubic feet per second) at the gauge. The exact loss of water between the head of this ditch and the measuring box is shown in the following summary, taken from the official records for the month of August for the years 1875 to 1882, inclusive. This month is taken as a dry month, as prior to that time the numerous side streams swell the amount delivered at the gauge.

* Increase capacity of this ditch is limited by the pipes across Humbug Canon.

† For details of Texas Creek ditch flume, see paper by Hamilton Smith, Jr., Transactions Am. Soc. C. E., Vol. XIII, pp. 30-31.

* The grades given in all the above cases, from which the different values of C were calculated, exclude the drops, chutes, flumes, etc. Sectional areas represent minimum cross sections.

RECORD FOR AUGUST.

	Water turned at Milton, 24 hours, inches.	Water turned at Bloody Run, 24 hours, inches.	Per cent.
1875	44,000	34,950	79.4
1876	59,700	42,625	71.3
1877	67,875	44,700	65.9
1878	76,050	58,875	77.4
1879	82,725	51,350	62.0
1880	74,080	55,325	74.7
1881	66,850	48,325	72.3
1882	68,300	50,984	74.4

The Eureka Lake ditch, with 2500 inches turned in at the head, delivers at the gauge, thirty-three miles distant, about 1800 inches in the dry season.

The above statistics lead to the adoption of values of the coefficient c, varying from 31 to 45, in estimating the capacity of ditches on heavy grades of forty miles length flowing from sixty to eighty cubic feet per second, such as referred to—that is:

$$Q = 31 \text{ to } 45\ a\sqrt{rs}.$$

The loss incurred in the distribution of water is denoted by the following figures, taken from the official records of two mining companies. The amount received is measured, at or near the distributing reservoirs; the amount used, at or near the pressure boxes. The difference shows the losses from leakage, evaporation, absorption, and wastage arising from excess of constant supply over the amount needed, with interruptions at the claim.

NORTH BLOOMFIELD COMPANY (24 HOUR-INCHES).

Year.	Amount Received.	Amount Used.	Loss.
1870 to 1879, including	5,838,865	5,504,758	334,107=6 per cent.
1880	945,550	920,612	24,938=2½ "
1881 *	950,340	866,962	83,378=9 "
1882	1,025,880	1,005,977	19,903=2 "
1883	862,660	836,251	26,409=3 "
14 years	9,623,295	9,134,560	488,735=5 per cent.

MILTON COMPANY (24 HOUR-INCHES).

1882	685,933	635,884	50,049= 7 per cent.
1883 †	446,224	361,877	84,347=19 "
2 years	1,132,157	907,761	134,396=13 per cent.

* Much water ran to waste during 4 months, owing to cessation of work caused by litigation.
† English reservoir was destroyed June 18, 1883, from which source the main water supply was obtained.

SPEED ON CANALS.

BY FRANCIS ROUBILIAC CONDER, M. Inst. C. E.

From Proceedings of the Institution of Civil Engineers.

I.

THE amount of resistance to the propulsion of vessels through narrow channels, due to the size, the form, and the surface of the channel, has not hitherto been fully studied. That this resistance increases in some ratio to the diminution of free water-way is known. In the "Minutes of Proceedings" will be found the statement that a steamer which attained a speed of from 16 to 18 miles an hour at sea, could not make more than from 8 to 9 miles per hour in the narrowest part of the Clyde; and that a boat which had a speed of 10 miles per hour in the Liffey, could not make more than 7 miles per hour in the Royal Irish Canal. The instant acceleration of a boat on passing into deeper water, which was mentioned in the debate cited, is well known to all boating men. But no formula for determining the proportion is to be found in engineering text books.

It was the advice of the author, on being consulted on one of the most important hydraulic projects of the day, that there should be instituted, in the first place, so thorough an investigation of the main scientific questions involved as to leave

no point open to hostile criticism. Among the special steps recommended to this end was "the commencement of a series of experiments for determining the form of cross-section best suited for canal navigation." The recommendation not having been carried out, the author has endeavored to apply to the elucidation of the question certain known facts as to the movement of water in channels of various forms, and as to the movement of vessels in open waters. As to the first, the experiments of Darcy and Bazin have been chiefly of use; and as to the second, those of the late Mr. W. Froude, M. Inst. C. E., on the wave-making resistance of ships.

Since the commencement of the inquiry, its importance has been accentuated by the extraordinary degree of attention that has been excited by the Suez Canal, and by the remarkable phenomenon of the retardation effected in the passage of vessels, although not amounting to an average of five each way per day. The average time occupied in actual movement through the canal has increased from seventeen hours per ship in 1876, to eighteen hours sixteen minutes in 1881, and to eighteen hours fifty-seven minutes in 1882; the speed slackening from 5.88 to 5.47 and 5.27 miles per hour. The time passed in the canal by each vessel has risen from thirty-nine hours in 1876, to fifty-three hours forty-six minutes in 1882. And a very recent report cites three cases of English mail steamers detained for seventy-one hours each in the canal. It is thus undeniable that the question of canal capacity for transport assumes a foremost rank among the practical engineering problems of the day.

In the absence of direct experiment, the only method available for the purpose of research is the comparative method. By this, mathematical considerations may be illustrated to a certain extent; and it may be at all events hoped to get so far as to determine where direct experiment becomes indispensable.

A vessel in its progress is continually displacing a mass of water equal to its own submerged bulk. This mass is usually calculated as proportional to the greatest immerged cross-section of the vessel; an approximation sufficiently close for the present inquiry. In open water, the vacuum that would otherwise be left in the wake of the vessel is filled by the water rushing in from all sides. It is unnecessary now to inquire how this movement of the water affects the speed of the vessel, as the ordinary performance of the latter in open water is taken as the unit of comparison.

When the movement of a vessel takes place in a restricted channel, the case is altered. There is no longer an indefinite supply of water all round the vessel to rush into the hollow at the wake. That hollow is filled, either by water which follows the movement of the vessel through the canal, or by that which flows as a counter current, being driven by the head due to the wave caused by the vessel. The first of these two actions is so limited that it may be neglected except in river navigation. The backward current, taken alone, will be directly as the speed and as the cross-section of the vessel, and inversely as the free water-way, or excess of the cross-section of the canal over that of the vessel.

Thus a vessel moving through a restricted channel has to encounter an opposing current which is a function of her own movement. Her speed will be the resultant of her proper motion and of that of the current, in so far as it affects her, and will be, roughly speaking, the difference of the two speeds. It is thus possible to obtain, subject to further elucidation, a general formula for the retardation of a vessel in a canal due to the back-current produced by her own movement.

Let A = the cross-section of the canal;
a = " " " vessel;
$n = \frac{A}{a}$;
V = the speed in open water;
y = the back-current in the canal;
x = the speed of the vessel in the canal.

Then $V = x + y$,

and, as the free water-way is $= (n-1)$ to 1, $y = \frac{x}{n-1}$;

therefore $$V = x + \frac{x}{n-1} \quad . \quad (1)$$

Let, for example, $n = 4$.

Then $V = x + \frac{x}{3}$,

and $x = \frac{3}{4} V$.

It results, however, from the experiments of Darcy and Bazin, as well as from theory, that not only must the area of the channel be regarded, but also its form, and the special nature of the wetted surface. Of all forms of channel, according to this authority, the semi-circular is that which offers least resistance to the flow of water; as it is also that of which thehydraulic radius is the largest, in proportion to the area.

But the hydraulic radius, or the area divided by the wet perimeter, $= \frac{a}{\frac{\pi}{2}}$, is approximately the same for a semi-circle and for a semi-ellipse of equal area. It will be at once admitted that, if an ellipse be taken of which the axes are. for example, as 6 to 1, it would be rash to assume that the flow of water would be the same through two equal semi-elliptical sections, one with the minor axis vertical, and the other with it horizontal. The periphery in each case would be exactly the same, and thus the ordinary formula, as dependent on the hydraulic radius, would be the same, and the volume and weight of water would be the same. But the hydrostatic pressure on the periphery, and therefore the frictional resistance, would be very different. Here, then, is a case where present formulas are inadequate fully to investigate the question of speed.

For convenience of navigation, the top width of a canal may be generally taken as from 7 to 10 times its depth; and, with the reserve just mentioned, the formula of the hydraulic radius may be applied to a semi-elliptical section of this proportion, as if it were a semi-circle. With this allowance, the formula above given, corrected for any difference of the hydraulic radius, as below exemplified, may be applied to those few facts which are attainable in the absence of further experiment.

The Suez Canal has a depth of 26 feet; a bottom width of 72 feet; sides sloping at 2 or 2½ to 1 to within 5 feet of the water-line, and a top width of 326 feet. Thus, with the exception of one or two portions of the course, there are flat shallow shoulders on each side of the navigable channel, which is only 112 feet wide at a depth of 16 feet. The area of the cross-section thus formed is 3,862 square feet, and the hydraulic radius is 12.34 feet at best, and in some parts of the canal not more than 10.12 feet.

A semi-elliptical section, 163 feet wide at top, and 30 feet deep in the center, would have an equal sectional area of 3,862 square foot, and a hydraulic radius of 21.31 feet. Thus, according to the usual estimate of the value of the hydraulic radius, whatever be the resistance due to the back current caused by the movement of a vessel in the canal (as determined by the formula $V=x+y$), it will be increased, owing to the resistance to that current due to the bad form of the trapezoidal section, as measured by the hydraulic radius. This as before observed, is treating the semi-ellipse as equivalent to a semi circle. A comparison of the two sections will show, that the fair-way afforded for vessels of 20-feet draught by the semi-elliptical section would be equal to that obtained by widening the existing trapezoidal section by 28 feet. But the present inquiry is as to retardation due to section.

In 1870, the "Warrior" steamed through the Suez Canal in twelve hours and fifty minutes, being at the rate of 6.85 knots per hour. The vessel of that name in the Royal Navy is 380 feet long; and, with an immersed midship section of 1,219 superficial feet, and an indicated H.P. of 5,469, is credited with a speed of 14.386 knots at sea. The application of the previously given formula (1) will be as follows:—

$A=3{,}862$ square feet.
$a=1{,}219$ "
$n=3.16$.
$V=14.356$ knots per hour.
$y=\frac{x}{2.16}=4.544$ knots per hour.
$x=9.812$ knots per hour.

The back-current y has thus a velocity of 7.68 feet per second. As the hydraulic radius of the canal is only about one-half that of the best form of channel for an equal cross-section, the resistance due to this speed (58.98) has to be doubled, and the square root of the product abstracted. This gives a retardatory current of 10.86 feet per second, or 6.429 knots per hour, and reduces the value of x to 7.927 knots per hour. The speed

actually maintained was only 6.83 knots per hour, and the amount of direct retardation due to the section of the canal might account for the difference. But the state of the canal in 1870 was such as to reduce the maximum speed in several parts of the course, although a higher speed is attained through the lagoons. In point of fact, the speed obtained has generally been regulated rather by regard to the damage caused to the banks by the wave produced by the steamer than by other considerations.

On application to the Admiralty to ascertain whether the ship in question was really H. M. S. "Warrior," it proved that it was not. In 1874, according to a Parliamentary Return (C. 1392, 1876, p. 69), a British ship called "Warrior," of 797 tons net tonnage, was re-measured by the Suez Canal Company. The area of cross-section of a vessel of this size will be only about one-fifteenth part of that of the canal. The retardation from back water will therefore be only one-fourteenth part of the speed, and the smaller vessel, with proportionately much smaller horse-power, will beat the larger in a restricted channel.

In the Forth and Clyde Canal, according to a statement lately published by Sir Arthur Cotton, R. E., the sectional area of the canal is three times that of the boats. A speed of 7 miles per hour in the open river is reduced to 5 miles per hour in the canal. According to the formula (1) (taking areas alone, without correction for the hydraulic radius), a speed of $7\frac{1}{2}$ miles per hour in open water would be reduced to seven miles per hour where the channel has an area between ten and twelve times that of the boat, and to 5 miles an hour where the areas are as 3 to 1. On the River Lee, according to the late Mr. Beardmore, M. Inst. C. E., with a boat having a cross-section of 50 square feet, an increase of section from 165 to 209 square feet was attended by an increase of speed of $\frac{3}{4}$ mile per hour. It is not, however, stated on what speed the increase was obtained. At a rate of motion equal to 10 miles per hour in open water, the difference of velocity due to the difference of areas would be 0.6 mile per hour, and there would be a slight further gain due to the improvement of the hydraulic radius. These examples, deficient as they are in precision, may perhaps be taken as evidence that the effects of retardation due to restriction of area, and to bad forms of channel, are by no means exaggerated by the formula above suggested.

The effect of rough sides, projecting jetties, and the growth of weeds, either at the side or at the bottom of the canal, as also that of mud in suspension in the water, have further to be taken into account as increasing retardation. Coefficients of some of these conditions are given in standard works on hydraulics. The effect of all such obstructions must be to retard the flow of the back-current along the sides or the bottom of the canal. But as the back-current, as a whole, is a function of the speed of the boat, this retardation of a part of it must be accompanied by a corresponding increase of speed in the part of the current farthest from the obstacles, that is to say, against the sides of the boat. It is thus evident why the foul state of a canal or river exercises that directly retarding influence on speed of transit which persons familiar with canal navigation know to be produced under such circumstances.

There is one important point as to which direct experiment appears to be necessary before it can be attempted to formulate a complete theory of retardation in canals; that is, the respective influence of width and of depth on speed. As to this, the data at present available have somewhat anomalous results. Thus, on an Indian canal, 60 feet wide, an officer in charge of the Madras Public Works department informed the author that as the depth of a long reach increased from 6 to 12 feet, the speed of a light steamer increased from 5 to 10 miles per hour. And the extraordinary starts, mentioned by several of the speakers in the debate above cited, made by boats in passing into deeper water, seem to be more rapid than is explicable by mere difference of area.

It may probably be found that these apparent anomalies are referable in part to the relation between the form of the vessel and of the wave that it produces, and that of the canal. Thus, on the Indian canals, where the boats have a draught of from 15 to 21 inches, and a horizontal entrance, being in some cases

propelled by a single paddle-wheel at the stern, the displacement of the water is effected downwards, and the slightest variation of depth is instantly felt. In other cases, especially in river navigation, where the entrance is vertical, and throws a wave to either side of the channel, it is possible that the effect of a change in width may be more directly felt than that of a change in depth. As to this, although a simple formula may be suggested, direct experiment is highly desirable.

Where the cross-section of a canal is very small in proportion to that of the craft navigating it, the advantage to be obtained by enlargement is most conspicuous. Thus, for the same boat, in passing from a canal where $A=2a$ into one where $A=3a$, there will be an increase of 33 per cent. in speed in the latter as compared with the former. Suppose the same speed to be maintained in the two cases, the cost of traction will be nearly as 8 to 5. Considerations of this nature are of the highest importance, as determining the section that should be given to any new canal. In the case of a ship canal, which is the class of enterprise on which much public attention is now concentrated, it appears from the preceding investigation that a gain of 1.8 knot per hour may be attainable by the adoption of a scientific section, without any increase in the quantity of excavation. This is equal to a gain of from 17 to 18 per cent. in time; or, if the same speed be maintained, to about 21.5 per cent. in cost of traction.

The speed maintained on inland waterways is kept down by (1) the changes of level; (2) the increase of resistance, which is as the square of the velocity; and (3) the fear of eroding the banks. Fig. 6 shows the ratio of increase of resistance to increase of velocity in open water.

Human labor is still employed for towage on some of the Dutch, Belgian and German canals. Boats of from 15 to 26 tons are towed by men at a speed of 1 to $1\frac{1}{3}$ mile per hour. Dr. Meitzen, a German authority, allows a duty of 11 miles a day, including all stoppages.

Steam tug-boats on the Belgian canals are restricted to a speed of $2\frac{2}{3}$ miles per hour, and on the wider rivers to $4\frac{1}{2}$ miles per hour. On the canal joining the Tiege to the Vistula, steam-tugs draw trains of barges 410 feet long, the speed being restricted to 3 miles per hour. The steam-tugs put by Mr. Beardmore on the River Lee towed from 50 to 60 tons, at from 2 to $2\frac{1}{2}$ miles per hour, in the cuts, 3 to $3\frac{1}{2}$ miles per hour in the larger sections, and 5 miles per hour in the Thames. On the Grand Junction Canal the speed of a steamer towing one vessel is put at from 3 to $3\frac{1}{2}$ miles per hour. On the Rotterdam Canal four boats, of 130 tons each, are towed by a propeller steamer, which also carries cargo, at 5 miles per hour. In Sweden, as well as in Holland, where the channels are narrow, the usual speed is $3\frac{1}{2}$ miles per hour, but 5 miles an hour is generally attained, the difference depending on the area of cross section.

In curves and shallows, in narrow canals or rivers, a breaking wave first appears at from 3 to $3\frac{1}{2}$ miles per hour. At 4 miles an hour the effect of the wave on the banks becomes injurious. At 5 miles an hour the wave increases, breaking over the towing-path, and being followed by other waves in succession. In parts of the Clyde from 120 to 150 feet wide, and about 10 feet deep, vessels of from 120 to 150 feet long, with from 16 to 18 feet beam, and from 5 to 6 feet draught, are propelled by engines of from 80 H. P. to 100 H. P., at a speed of from 8 to 9 miles per hour. At this speed a surge rises at from 2 to 3 miles ahead, and a wave is caused which measures 8 or 9 feet from the crest to the bottom of the trough. A head of this height gives a theoretic speed of 16 miles an hour, which shows a loss of 50 per cent. due to restriction of channel.

A speed of 5 knots per hour, or 8.37 feet per second, corresponding to a head of 1.08 foot of water, is the limit of speed fixed for the Suez Canal. This may perhaps be taken as the normal speed to be sought on the canals of England. On the determination of the normal speed, and of the tonnage of the boats to be accommodated, will depend not only the steam power required, but the section of the canals and the dimensions of the locks. A speed of about 30 miles a day, including stoppages, is even now attainable on English canals.

The loss of time due to locks is more serious on many English than on most continental canals, although there are

canals in Belgium with far more numerous locks than the average in England.

A rise of 8 feet is overcome on some canals in three and a-half minutes. On the Aire and Calder Navigation, Mr. Bartholomew, M. Inst. C. E, has attained a rise of 7 feet 6 inches in two and a-half minutes, and a rise of 13 feet 6 inches in three and a-half minutes. These figures give the rates at 2.3, 3, and 3.8 feet per minute, either for ascending or for descending, a speed which may probably be increased by better construction of locks.

By the use of lifts or of inclined planes, where a rise can be concentrated, much greater speed than the above may be attained. A height of 51 feet is cleared by the Anderton lift in eight minutes. On the Morris canal incline a height of 51 feet is overcome in three and a half minutes; and on the Blackhill incline, on the Forth and Clyde Canal, a height of 96 feet is overcome in ten minutes. The corresponding speeds are 6.37 feet, 14.5 feet, and 9.6 feet per minute, or about three times the speed now attained by locks.

The heights to be overcome in crossing England from the Thames to the Severn are, 358 feet on the 204 miles of the Wilts and Berks route, 474 feet on the 180 miles of the Kennet and Avon route, and 392 feet on the 206 miles of the Thames and Severn Canal route. This gives an average change of level, counting ascent and descent, of 4.14 feet per mile, or a little more than one-fourth of the ruling gradient laid down by Mr. Robert Stephenson for the London and Birmingham railway. From the Report of the Select Committee on Canals, p. 125, it appears that on 2,440 miles of canal there exist one thousand nine hundred and one locks, or a lock to every 1.37 mile. This gives an average rise or fall for the system, as far as it is represented by the times returned, of 5.84 feet per mile. At the rate of 3 feet per minute, these figures show a retardation of from 1 to 1.75 minute per mile over the Thames and Severn lines of junction, and of 1.95 minute per mile as the general average.

Taking the more uneven section, a running speed of 5 knots, or of 5.76 statute miles per hour, on an ordinary English canal, will be reduced by the delays caused by the locks to a speed of 4.9 miles per hour; allowing of the performance of a distance of 58.8 miles in twelve hours, or nearly double the speed of prompt canal service at present. This is about one-third of the running speed of the mineral trains on the railways of the United Kingdom. But a terminus to terminus speed of 5 miles an hour is as much as is sometimes attained by the mineral trains; and it is in evidence that the deliveries of despatches made by river and canal from Gloucester to Birmingham are as prompt as those made by railway between those two important towns.

The cost of speed on railways may be ascertained by analyzing the expenditure, and arranging it under the heads of costs independent of velocity, costs increasing with velocity, and costs decreasing as velocity increases.

The object of the author in the foregoing paper has been, first, to call the attention of the profession, and of those who consult its members, to the character of the experiments which are requisite for the determination of the true theory of loss of speed in canals; and, secondly, to propose an hypothesis, illustrated by such facts as are at present on record, according to which future observations may be so grouped as to lead to the ultimate determination of the true theory.

DISCUSSION.

Sir Joseph Bazalgette, President, said, as the paper had taken a large and comprehensive view of the subject, it was perhaps a little difficult to know exactly how to treat it so as to make the discussion most effective. Probably the best way would be to treat first upon the practical and theoretical considerations which govern the section of a canal with reference to the traffic to be passed through it; next to deal with the best means of traction along the canal; and then to draw a comparison between the cost of transit by inland canals and railways. If the discussion was divided under those three heads by those who were about to speak, more effect would be given to the arguments which might be deduced therefrom.

Mr. Conder said he had only been able to touch the fringe of a very large

subject, and one which must be of great interest to the members of the Institution, as it was to all the manufacturing districts of the country. It was a subject on which the Continent was greatly in advance of England. In Belgium, Holland, Germany and France, inland navigation had an importance quite equal to that which it assumed in England before the commencement of railways. In France, at the present moment, a very large sum was annually laid out by the State for the completion of the internal navigation of that great country, which would allow vessels of 120 tons to pass from sea to sea and from frontier to frontier. The question of the comparative cost of land and water transport, which had been repeatedly and carefully investigated in France by the Chamber of Deputies, by the Senate, and by the Ministry, had not been hitherto investigated to any great extent in this country, although it was now being considered by a Select Committee of the House of Commons. He had to apologise for bringing the subject before the Institution at a somewhat late period, but that was not altogether his fault. He had knocked three times at the door of the Institution in the hope of introducing the subject. He had not a word to say against the wisdom of the Council in the selection of papers, but he thought it due to himself to make the apology which he had done for not having brought forward the subject earlier and in the first instance, before the Institution. He had, however, the advantage that he could now set aside the question of pounds, shillings and pence, because the evidence printed by the Select Committee upon canals was so full and clear as to have settled the question of comparative cost. Members would find in the evidence, and in the tables attached to it, the cost of land and water transport in Austria, Belgium, Germany, France, Italy, the United Kingdom, the United States, and New South Wales, in sea passages from Liverpool to New York, from England to Bombay and Calcutta, and in coasting steam collier passages. There was a sufficient accord in all those various sources of information to enable any one to see that, in round numbers, the cost of inland water-carriage did not exceed one-third of the cheapest cost of inland land-carriage, even with the great advantage of the railway system. It was, however, but fair to mention that the railway lengths were almost invariably shorter than the canal lengths; and therefore from the two-thirds there would have to be deducted the difference between the ordinary length of the railway and the ordinary length of the canal. That, however, would still leave the cost considerably less than one-half. As to the question of speeds, it might be taken that the proportion was as a day to a week. There was so much loss of time in shunting, and in the terminal distribution of mineral traffic by railways, that many witnesses before the Committee had given distinct evidence of delivery in equal time by railways and canals. But taking the proportion as a week to a day (which was least favorable to canals), it appeared to him that what the manufacturing interest of the country demanded was to be able to choose whether or not it would pay for speed. If manufacturers had the choice of taking a week for their work and paying accordingly, or sending their goods in a day and paying accordingly, a sifting of traffic would take place which would enormously benefit the railway shareholders. A very much larger tonnage could then be carried upon railways, because only that kind of traffic would be carried which could afford to pay for rapid speed; a proportionate rate would of course be paid, and two or three times the amount of goods could be carried on the same track. He wished to point out that the actual capacity of a conduit, whether a canal, a railway, or a pipe through which a stream of bullets was dropped, did not depend upon actual speed. At whatever speed a number of trains or boats were sent out, they would arrive the same distance apart at the other end, and in the course of the year the same amount of traffic would pass over the line. The moment a different speed was introduced, the line was strangled, and its power of conveying traffic greatly diminished. Take as an instance French railways and English railways. It was perhaps not generally known that the earnings of the six great French railways during ten years, from passengers and goods alone, had been nearly pound for

pound per mile the same as on the English lines. The English earnings included in addition about £800 per mile for mineral traffic, which was not represented on the French lines, because, although on the Great Northern Railway of France there was a considerable mineral traffic, it was at a freight so much higher proportionally than the English freight that it did not greatly affect the comparison. Taking the legitimate railway traffic as equal, and taking the mineral traffic, on which certainly not more than 10 per cent. profit was made, as additional transport on the English lines, it would be found that the capital of English lines was upwards of 50 per cent. more than that of the French lines. It seemed difficult to conclude otherwise than that there was thus laid on upon English lines 50 per cent. more cost for the sake of carrying a double and mixed traffic; and that upon a third of the capital the receipts were only £80 net per mile. He desired to call attention to Fig. 6, showing the effect of speed on the cost per hundred ton-miles. The diagram showed the costs of the railways of the United Kingdom for 1878, distinguishing those which he considered to be independent of speed, those which increased with speed, and those which diminished as speed increased. The second, he presumed, would be principally for fuel; but he had added the whole cost of the locomotive repairs. It would be seen that there was a certain point, which on the average of English lines was about 30 miles per hour, where the lowest cost was attained by the running speed. Thus the idea of saving by running enormously heavy trains at lower speeds was a mistake, because, although there was a considerable decrease in the cost of fuel, the increase in wages was sufficient to eat it up. On the question of hydraulics there was an expression in the paper to which some of his brother engineers would probably take exception. Whether he was right or wrong, he had not made the remark either from neglect or ignorance. He was willing to bow to any correction he might receive, but he desired to explain his own views. He had spoken of the sweeping, rolling force of water as being determined by the total hydraulic pressure. He was aware that he was in opposition to the text books, and also that the supreme authority of Newton would be quoted against him. He had, however, gone through the passage in Newton, which would be found in a long scholium to the fortieth Proposition of the Second Book of the *Principia*. Newton made a number of beautiful experiments by dropping balls of wax loaded with lead through 15 feet. of water, and he connected with those experiments the dropping of various bodies from the dome of St. Paul's, for a height of 200 feet, and his result was that resistance in a fluid was proportionate to the density of the fluid, and not to what was understood as hydrostatic pressure. With that he unhesitatingly agreed. There had also been some beautiful experiments of Coulomb to the same effect. He had vibrated plates in water by the torsion of wire, and had arrived at the same result. The result indeed was an integral part of Newton's system, and he supposed that no one would be bold enough to question it. But it should be remembered that that was a consequence of the incompressible character of water. In air it was not exactly the case, although as far as Newton's experiments went he had not the means of telling the difference; but the air being more compressed near the surface of the earth, according to Newton's own theory, the resistance would be greater, and therefore the velocity would be checked. To say that friction in a fluid was the same thing as the friction of the fluid itself rushing over the surface of the ground, appeared to him to be contrary to common sense. It was in fact saying that if there was a river slope, or a mountain side, down which there was poured an inch of water at a given velocity, which was regulated by the slope, and then the inch was increased to 10 feet of water, that quantity, at the same velocity, would not erode the bed of the mountain side more than the inch of water would erode it. It required no argument to show that such a statement would be absurd. That view of the case, however, struck at the root of all existing hydraulic formulas. In questioning the accuracy of those formulas, he wished to support himself by the authority of men whose names were well known. Among the latest books on the subject published in this country, were those of Mr. L. D'A. Jackson. He would

say nothing of the books themselves; but would only refer to the testimony in them of the utter valuelessness of all hydraulic rules. Mr. Jackson had pointed out that of three sets of formulas the results were utterly irreconcilable. Professor Macquorn Rankine had also plainly stated that there was no general hydraulic theory for the laws of the friction of fluids, and that it was necessary to adopt a rule of thumb, and arrive at the result in the best way possible. So also with regard to the paper read before the Institution by Major Alan Cunningham,* in which so many minute measurements were given, the result was still the same —the want of a general theory. Amongst those who had studied the question was Mr. Graef, the author of the latest mathematical book on hydraulics, who had endeavored to apply the resources of analytical investigation in tracing the movement of every filament of water, and the result at which he had arrived was that the only thing that was absolutely clear was *la courbe des debits*. That meant taking a certain vertical in a river and gauging the actual passage of the flood from time to time, and comparing the passage of the flood and the height of the hydrometer, and plotting the heights and quantities. None of them, he said, were perfectly right, but by plotting them and then drawing a fair curve through them, the best result would be obtained. That was the very latest outcome of the highest mathematics on the subject. It appeared to him that the difficulty to be contended with was the thoroughly non-mathematical character of the formulas. The formula $V = c\sqrt{rs}$ was the basal formula of all hydraulic works. It was represented in a more elegant form by Hagen, who gave $V = C.\ R.^{x}\ I.^{z}$ The former formula might be considered as indicating the square root, but American engineers were not satisfied with the square root; they had plotted the third and fourth root and some others to see which fitted best, and found that for one set of experiments the square root was best, for another the cube root, and for another the fourth root. For that reason he thought that Hagen's formula was more intelligible than the ordinary one. But he ventured to attack the ordinary formula root and branch as erroneous in every item, and proposed to substitute for it the simple formula $V = u + v - r$, where u represented the measured velocity at the entrance on a given section, v the theoretic acceleration due to gravity on the section, and r the sum of resistances in the section. These once determined, would then be of permanent value.

Mr. J. H. Taunton was quite sure that the Institution would appreciate any efforts made by new minds in the advance of science to build upon old foundations so long as those efforts were based on the results of experience. He thought the author had not quite understood, or that he had underrated, what had been done before in ascertaining the resistance due to the passage of boats through narrow channels. One of the founders of the engineering profession—Smeaton—had studied the subject in early days. He had also studied the form and proper section of a canal, and he stated that the proper speed on a canal for a horse to travel was from 2 to $2\frac{1}{2}$ miles an hour, and that the useful effect of the horse was 650 tons hauled 1 mile in a day. Whether the horse had been replaced by another agent or not, the effect calculated still remained. Subsequently Mr. Bevan had investigated the same subject with similar results. There was also the extended experience of a Past-President of the Institution, the late Mr. James Walker, who in May, 1827, submitted a paper to the Royal Society, "On the Resistance of Fluids to Bodies Passing Through Them."* Still later there was the experience of the late Mr. H. R. Palmer, Vice-President Inst. C. E., who had made a variety of experiments on the Ellesmere canal, the Grand Junction, and other canals in different parts of the country, especially the Irwell and Mersey canal.† Those experiments had been investigated by Professor Barlow, who derived from them the conclusion that the resistance to the passage of boats through such canals as existed in this country was as the cube of their velocities, and not, as stated in the paper, the square of their velocities. There were also a variety of experiments, conducted by means of fly-

* Minutes of Proceedings Inst. C. E., vol. lxxi. p. 1.

* Philosophical Transactions, 1828, p. 15.
† Transactions Inst. C. E., vol. 1, p. 165.

boats, upon which the late Sir John MacNeill was requested to report.* The result of the experiments was that with a velocity of 2½ miles per hour the power necessary to move 1 ton was 2½ lbs.; with a velocity of 4 miles an hour from 7 to 11 lbs.; and with a velocity of 5 miles an hour (which was spoken of by Mr. Conder as the velocity with which boats were to traverse canals in future), the tractive force necessary was from 20 to 30 lbs. Those results were not encouraging, and did not point to the success of any suggestions such as those made in the paper. They did not point to any means of working traffic at a faster rate than it was worked at present, and they showed conclusively that the proper rate for moving heavy goods on canals such as existed in this country was from 2 to 2½ miles per hour, which agreed with Smeaton's original calculation. He would not enter into the question of the formula referred to by the author, except to say that it did not appear to him to be of a sufficiently distinctive character to show what resistance was due to the width and what was due to the depth of the canal. He might be permitted to mention some experience of a practical character bearing on the subject of boats traversing canals. Midway on the Gloucester and Berkeley Canal, which was a length of level water of about 16 miles, was a place called The Junction, where it joined the Stroud water canal, about 8 miles from Sharpness. Boats built with a longitudinal bottom traversed that distance of 8 miles with an ordinary horse, and carrying 60 tons, in about three hours, while boats of the same character, built with a cross-bottom, required about four hours to traverse the distance, the slight difference being that the angle of the boats built with longitudinal plank was removed. That was a fact within the experience of all the boatmen who worked on that navigation. On the navigation with which he was especially concerned, the boats were built so as to carry as large a cargo as possible, and they had perfectly flat cross bottoms; while the boats on the Wilts and Berks Canal had a cradled bottom and a keel. Their own boats, after the horse was unhooked, would pull up in little more than their own length, while the other boats with a keel bottom would run three or four lengths before stopping. Those were simple matters, but they were indicative of points of some importance bearing upon the subject under discussion. As reference had been made to the Thames and Severn Canal, which he had had under his management for many years, he might be allowed to say a few words on the subject of lockage. He could not conceive anything more erroneous than the way in which that subject had been treated by the author, who had stated the total distance from the Thames to the Severn to be about 206 miles, but it was really 186 miles. The height of the summit level above the sea, instead of being 392 feet, was 365 feet. The author had taken the whole length and doubled the ascent and descent for lockage, and so obtained 4.14 feet as the average fall per mile, which he stated was much less than the ruling gradient of the London and North-Western Railway. That was a singular way of obtaining a ruling gradient. Whatever might be done upon a railway, it was certainly not the way to deal with the flat level water such as was traversed in a canal. In the Thames and Severn Canal, which crossed the Cotswold Range, there was a lockage ascent from the Severn of 365 feet, and then a descent to the valley of the Thames of 128 feet, the ascent per mile being 24 feet, and the descent per mile 10 feet. He had worked it out carefully, taking the total mileage and the levels. The author proceeded to say that Mr. Bartholomew had attained, in emptying his locks, a speed of 3 feet in a minute; that was very likely. No doubt, with large paddles, a speed of that kind might be obtained. In order to find the speed attained on the Thames and Severn Canal, he had on the previous day made observations on the passage of a boat through three locks, and the result of those observations was that the locks, having a capacity of about 10,000 cubic feet, filled and carried an ascending boat in six minutes, and emptied for a descending boat in five minutes. There was a difference in speed, because there was a difference of velocity at the paddles. The lower gates having a greater head of

* *Ibid.* p. 237.

water on them than the upper gates. The locks were 8 feet deep, giving somewhat more than 1 foot to a minute. On the narrow canals, only 7 feet, there was a greater speed, because, instead of 10,000 cubic feet, the contents to be emptied were only 5,000 cubic feet. No doubt there were some locks which could be cleared in from two to three minutes. It was not, however, the question of the speed attained, but it was the practical question of working the locks that had to be considered. A boat was of course delayed in approaching a lock, and it might have to be tied up for a time on arriving there. Wanting the lock empty, the boat might find it full, waiting for a descending boat. The result of his own experience was that it took twenty-four minutes per mile for the ascending locks, and ten minutes per mile for the descending locks, and the result was that in a distance of 35 miles it took eight hours and twenty-one minutes in working through the locks. It would seem, therefore, that any calculation founded upon the idea of 1.37 minute per mile due to lockage being sufficient was altogether erroneous as far as actual practice was concerned.

Mr. E. J. Lloyd desired to confirm what Mr. Taunton had said, by two experiments of his own with regard to the question of retardation. A steamboat with one boat following started from Stockton, Warwickshire, for London. The steamer carried 22 tons, and the following boat 29, making a total cargo of 51 tons. He had been told that the boat had traversed a part of the canals under his management at the rate of 4 miles an hour, and he thought he should like to investigate the matter somewhat further. Hearing that the boat was again in his district, he met her, and traveled with her over a portion of the canal where she was said to have acquired the speed he had named. He then found that she did acquire that speed, the canal at the point where the trial was made being exceptionally good. At a speed of 4 miles, for a distance of 109 miles, the passage would occupy twenty-seven and a-quarter hours. He had also measured the time occupied by the locks, in the same way as that in which it had been taken by Mr. Taunton, and he found that it varied, being on the northern section of the Warwick canals two minutes; on the southern section one and three-quarter minute, and on the Grand Junction two and a-quarter minutes. Taking the number of locks passed and the time occupied as above stated, it amounted to three hours nineteen minutes for passing the locks, making the total time occupied in motion thirty hours forty-five minutes. But he found that the boat took forty-nine hours to get to London, so that there was a retardation, due to other circumstances than the passage of the channel and the locks, equal te nineteen hours. Another boat started from Birmingham for London, a distance of 148 miles, and the time occupied was sixty hours; the cargo carried by the steamer being about 16 tons, and by the following boat 24 tons, making a total of 40 tons. The calculation was that the boat was to travel at 3¼ miles an hour. She was capable of passing in a cross-section of 120 feet at that rate; but it was found that in running over a section of 9 miles, she did the distance in exactly two and a quarter hours, which would be at the rate of 4 miles per hour. The time taken by the locks was five hours and six minutes, making a total of forty-seven hours and six minutes, showing a retardation by other causes of thirteen hours fifty-four minutes. It might be asked, how was the thirteen hours fifty-four minutes occupied? He had taken out the number of boats passing through that section of canal within the last year, and he found there had been issued upwards of 22,000 bills of lading, and this number of craft was exclusive of light boats, which were passing and re-passing on the canal, each one causing various delays to the progress of every other craft. One of the great causes of delay was that the boats could not arrive at the locks exactly at the right time. A rising boat might arrive just as the lock was beginning to get ready for a descending boat, and there was thus a considerable loss of time in waiting for turns. Another source of delay, he was sorry to say, was the non-removal of shoals. A third reason was the retardation of every boat in approaching a bridge, and in acquiring its full speed after it had passed. Sharp turns in the water-way and bad or indifferent hauling power also caused delays. Taking those matters into consid-

eration, and making an approximate estimate of what was lost by them, he found that it was not less than fourteen hours on the journey from London to Birmingham. The author had stated that a steamer on the Liffey attained a speed of 10 miles an hour, and only went 7 miles an hour on the Royal Canal. That was very likely because she would probably then be within 4 inches of the bottom, and there would be no room for the water to go under her. If there had been sufficient space for the under-current, she would have probably made another mile or a mile and a-half. The diminution of the speed in the Suez Canal was, in all probability, due to the fact that the current caused by the great draught of the vessels passing through the canal had carried off the top of the slope in the trapezoidal section at the bottom of the canal, and the displaced sand had narrowed the fairway of the canal at the bottom, and probably also somewhat diminished the general depth. He was not aware whether it had been ascertained that there had been any decrease in the depth of the canal, but he thought it very probable.

It was stated in the paper that Mr. Beardmore in some experiments upon the River Lee had got an additional speed of $\frac{3}{4}$ mile in consequence of a comparatively small alteration in a section. It so happened that he was with Mr. Beardmore on the occasion of one of his trials. It was not right to say that there was an additional speed of $\frac{3}{4}$ mile, because he believed the maximum speed was $3\frac{1}{4}$ miles, and the average $2\frac{1}{2}$ miles. The boat was altogether unsuitable for experimental purposes, and it was not very remarkable that when they got into deeper water they managed to go a little faster. With regard to the passage of water through locks, the late Mr. James Potter, M. Inst. C. E., constructed a new portion of canal in the neighborhood of Birmingham, which was now under his control. Mr. Potter speeded the locks at eight seconds per foot of fall. An endeavor was made to work the canal with paddles of the size required to attain that rate of fall, but it was found that the destruction of the canal works, more particularly at the lower end of the locks, was so great that it became necessary to stop up a portion of the water passages, and they still continued stopped up. It was found impracticable to work the canal with such a fall. Some years ago an experimental boat, to test the question of speed that might be attained on canals under particular circumstances, was built and sent to him. It had a deck 6 feet 10 inches in width, by 71 feet in length. It was built with the ends contracted from 7 feet from the stem and stern. The plating was of steel, $1\frac{1}{2}$ lbs. per square foot, and the ribs 1 lb. per square foot. There was a rib every 12 inches throughout the boat, and a light longitudinal rib also of steel and of a T section passed along on the top of the keelson. The machinery was guaranteed to attain a speed of 10 miles an hour, and it weighed 16 cwt. The entire boat, inclusive of machinery, weighed $3\frac{1}{2}$ tons. The forward draught was 1 inch, midship draught 4 inches, stern draught 5 inches. The total depth of side was 20 inches throughout. It had a midfeather 25 feet in length, starting from the level of the bottom of the boat, and attaining a maximum depth of 12 inches, along this the propeller shaft was carried. He made some experiments with it. In a canal of about 123 feet cross-section, that boat, only displacing $2\frac{1}{2}$ feet of water in maximum cross-section, could not be made to attain a greater speed than 5.62 miles an hour. He drove her through a tunnel having a cross-section of 90 feet at the rate of 4.8 miles. He found, when he got some distance into the tunnel, that, looking back into the darkness, and judging as nearly as was possible under the circumstances, the boat was followed by a wave caused by the counter-current having a fall from the crest to the bottom of the trough of 2 feet or more. Feeling assured that if this wave overtook the boat it would be inevitably swamped in the darkness, and probably all on board drowned, he was obliged to put the engine to its utmost speed to avoid being sunk in the deep water, and fortunately they emerged into the wider water at the mouth of the tunnel in safety. On coming into the daylight the horror-stricken face of the constructor of the boat presented an appearance he should never forget, nor could he forget his gasping exclamation, "Sir, in that tunnel I have been nearer the confines of eternity than ever I was before in my life."

Arriving at the next bridge he seized his bag, jumped ashore, and left his boat, his experiments, and everything else; he never came again.

The question of attainable speed was limited not only by the form of channel, but also by the form of boat and the relation of the displacement to the sectional area and to the depth of the waterway. The problem to be solved was, not what speed could be attained in a channel of indefinite area and of the form necessary to provide for the passage of the counter-current without delaying the progress of the boat at all, or to an unappreciable extent, but what form of channel was suitable, having regard to the capital outlay necessary for its construction, and to the economic results on an attainable weight of traffic? This, again, necessitated the consideration of the best form of boat, and its suitability to the class of cargo to be carried. As every canal carried various classes of cargo, and the craft plying thereon are required, in many instances, to pass into and across the tide-ways communicating with the outports, it was evident that the solution of the question by any formula was not practicable. It might, however, be assumed that the best cross-section of channel would be about equal to five times the maximum displacement of the largest craft navigating it, and that the depth should exceed the maximum draught by one-fourth at least, and the bottom width be equal to twice the beam of the widest boat. As to the form of channel, probably a semi-elliptical form was best, at equal cross-sectional areas; and in a channel closely approximating to this form very good results had been attained, but it was so costly in construction and maintenance that it was doubtful if it could be economically adopted.

On the other hand, a trapezoidal section with side slopes varying from 1 to 2 feet horizontally, to 1 foot vertically, according to circumstances, and having a bottom width fully equal to two beams of the largest craft navigating it, could be constructed at a much less cost, and probably the loss of speed would not be very important, especially if the form was somewhat varied by the introduction of dwarf walls on either side to about 3 feet under water-level, as was now being done on many canals having a large traffic. Even with the best attainable channel, not more than an average speed of three miles per hour could be maintained if economy in the cost of transport was studied, and it was self-evident that canals were not, under any circumstances, enabled to compete in speed with railways, and that their proper function was not so to compete, but to carry great weights of raw material and goods not requiring prompt delivery at a very low cost.

Many of the statements in the paper appeared to be wanting in precision, or not to be based on reliable data. For instance, it was stated that the vacuum caused by the motion of the boat "is filled, either by water which follows the movement of the vessel through the canal, or by that which flows as a counter-current, being driven by the head due to the wave caused by the vessel," and that "the first of these two actions is so limited that it may be neglected" in restricted channels. This was so far from being correct that the motion of the following water and its retardation by the irregularities of form of channel, and the presence of weeds and other impediments to its forward motion, formed a self-evident and easily appreciable cause of lessened speed, and the more restricted the channel the more evident this would be.

Again, it was stated, "Thus, for the same boat, in passing from a canal where $A=2\,a$ into one where $A=3\,a$, there will be an increase of 33 per cent. in speed in the latter as compared with the former. Suppose the same speed to be maintained in the two cases, the cost of traction will be nearly as 8 to 5."

No data were given on which the accuracy of this statement might be examined; but it was certain that such results were wholly at variance with known facts, and that increase of speed in direct proportion to cross-sectional area was not an invariable rule.

The question of the loss of time due to the differences of level was not clearly stated in the paper. It would be evident that a lock of small dimensions could be more rapidly filled than one of much larger cubical contents, with large locks such as were spoken of on the Aire and Calder, and with such a considerable rise as 13 feet 6 inches, three and a-half minutes was a very short time for filling the

lock chamber. On the Wilts and Berks Canal, with very small locks, 0.434 minute per foot of rise seemed a long and wasteful delay.

There was, however, as already stated, a limit to the rapidity with which a lock could be properly filled and discharged. In the case mentioned on the Warwick Canal, it was found that the bed of the canal was eroded to a considerable depth, and for some distance from the tail bay of the lock, the disturbed material being piled up and forming a troublesome shoal. On the Napton Canal, where the locks were—many of them—in very close proximity, he had adopted a plan of having a larger area of discharging passage at the head of the lock than at the lower gates, to avoid the difficulty spoken of by Mr. Taunton, namely, that consequent on the greater pressure of water on the paddles at the lower gates, a larger volume of water was discharged in the same space of time, causing irregularity of level and waste over the by-wash. The rapidity with which locks on a canal could be worked depended on more than one consideration. Where water was scarce and costly the locks were worked slowly to ensure the avoidance of waste; but in cases where water was plentiful, a far greater speed of discharge might be safely attempted. In practice, it had been found that with a canal bed of fairly solid material, such as clay or gravel, a speed of discharge equal to 1 foot in 0.25 minute might be attained. Where, however, the bed of the canal consisted of quicksand or peat, not more than 1 foot in 0.33 minute was safe, and this had in some cases been found too rapid. With respect to the experimental boat mentioned, it was an honest, although impractical endeavor to solve the question now under consideration. The originator of the idea who bore the whole cost, stated that "he desired to build a boat of exceedingly great buoyancy, which should, if possible, successfully demonstrate the possibility of attaining a very high speed on narrow canals." It was pointed out that this supposed buoyancy was an error, and that any extraordinary lightness of construction only gave additional cargo-carrying capacity at any given draught, and could in no degree govern the speed attainable. What the experiments did satisfactorily prove was, 1st. That the volume of swell and consequent counter-current was in a great measure due to the form of boat and its relation to the sectional area and not to the area of displacement; 2d. That the attainment of a running speed of 5.76 miles per hour on an ordinary English canal, as proposed in the paper, was impossible.

Sir Charles Hartley remarked that the author recommended that a series of experiments should be made to determine the form of cross-section best suited for canal navigation. It seemed to him that however useful the results of such experiments might prove to engineers in designing canals through very hard or rocky ground, they would be of little service in determining the best kind of profile for ship-canals through soft or sandy ground, where the adoption of flat side-slopes would be a necessity. In designing cross-sections for such important waterways, the chief consideration would continue to be as hitherto, the nature of the material through which the canal was to be passed, and how best to provide the greatest amount of accommodation for ocean steamers at the smallest cost. So far as he was aware, the floors of all canals had as yet been cut down to a perfectly level surface, with the view of giving the same draught of water over the whole width of the floor. In course of time, however, owing to slips in the banks in places where the upper parts of the slopes were not protected against wave-action, the cross-sections gradually assumed a rounded outline, and in this way the channel went on deteriorating at a rapid pace unless maintained at its original depth by dredging. Now, even supposing the form of as ellipse, represented the best kind of profile theoretically, taking into account the relation between the velocity and the resistance encountered by ships in confined channels, it would be an impossible section in soft ground, unless the sides were protected by walls of masonry founded, in the absence of benchings, at a great depth below the surface of the water, an expedient which he deemed to be inadmissible on account of the great expense which would attend its application. In French canals, the width and depth of the navigable channel were regulated by

the amount of traffic anticipated, and the class of vessels to be accommodated, and the slopes, as a rule, were 1½ to 1, varying, of course, where the nature of the ground rendered a flatter slope advisable. A similar profile, according to a recent number of the *Scientific American* was also being adopted in soft ground at the Isthmus of Panama near Aspinwall, where an American firm had contracted to dredge through 10 miles of what was called marsh-work, to a cross-section 100 feet wide at the bottom, 180 feet at the top, 27½ feet deep and with slopes at 1½ to 1. Another instance of modern French practice in ship-canal making was the St. Louis Canal, which was opened in 1872, and which he had two opportunities of visiting when under construction. This canal was 2 miles long, and flanked the mouth of the Rhone. It was cut through soft silt and fine sand, containing every here and there beds of hard clay. The cutting was 33 meters wide at the bottom, 63 meters at the top, and 6 meters deep over the whole width of the floor. The slopes had an inclination of 2 to 1 from the bottom up to 2 meters below low water, at which level there were benchings on either side 6½ meters in width. From these benchings the slopes were protected with smooth-faced stone walling in hydraulic lime. This revetment was carried up at an inclination of 45° to the level of 4 feet above the water line. It would be seen from this description that the cross-section of the St. Louis Canal closely resembled that of the Suez Canal. If, indeed, the lower slopes of 2 to 1 were extended to the depth of 8 meters, one would have a width of 22 meters or 72 feet, at the bottom, the actual width of the floor of the Suez Canal.

With regard to speed in ship canals it was stated in the paper that the speed of vessels in the Suez Canal had slackened from 5.88 miles per hour in 1876, to 5.27 miles per hour in 1882. Now the maximum rate of speed allowed by the Canal Company was 10 kilometers or 5.4 knots per hour, and this, as the author observed, had been regulated rather with reference to the damage caused to the side slopes by the waves produced than by other considerations. The average speed through the canal proper was really less than the author had indicated; for throughout the Bitter Lakes, in the open water from one lighthouse to the other, a distance of 8 nautical miles, vessels were free to steam as they pleased. With the view of protecting the banks from injurious erosion, caused by the high speed of passing steamers, the upper parts of the slopes of the canal, down to depths varying from 3 feet to 9 feet below the water line, were being gradually protected with smooth-faced masonry in hydraulic mortar, laid at inclinations of from 2 to 1 to 5 to 1, according to the nature of the ground. With regard to the average time occupied in actual movement through the canal, the author stated that the actual time passed in the canal by each vessel had risen from thirty-nine hours in 1876, to fifty-three hours thirty-six minutes in 1882. On reference to the latest statistics published by the Canal Company, he found that this statement was practically correct; but it should at the same time be explained that, although the average time occupied by actual movement in the canal was precisely thirty-nine hours thirty-two minutes in 1876, it had only risen to forty-one hours in 1880, and that the very marked slackening in speed in 1881 and 1882 was principally due to the establishment of quarantine from the month of September, 1881, to August, 1882. In 1883 an improvement took place, for the average throughout the past year fell to forty-eight hours forty minutes, notwithstanding that in March, owing to three storms of unusual violence, the average for that month rose to seventy hours ten minutes, and this of course affected the average for the year. With reference to the cross-sections of the Suez Canal, it should be observed that there was hardly any fixed section at present, and that the width at the water-line varied according to the ground traversed by the canal. Thus, although the navigable channel was uniformly 72 feet wide and about 26 feet deep, the width at the water-line varied from 200 feet in the long cuttings of El Guisr and Serapeum to 328 feet between Port Said and El Guisr, and throughout the Suez Plain.

The author mentioned incidentally that the cross-section of the Suez Canal was only about one-half of the area originally

intended. This statement was substantially accurate, and the circumstance was so important as to merit some more special notice on that occasion. In the "Avant projet" of 1856, and in the Report in the month of December of that year of the Suez Canal International Commission, on the roll of which appeared the names of Mr. Charles Manby, Honorary Secretary Inst. C. E., and the late Mr. J. R. McClean, Past-President Inst. C. E., it was stipulated that the canal should be wide enough, not only to allow two vessels to pass each other, but to give place to a third line of vessels which might, from whatever cause, stop on the way. It was therefore recommended, and provided for in the first estimate of £10,000,000 for the whole work, that the canal between the Red Sea and the Bitter Lakes should have a width of 64 meters, or 210 feet, at the bottom; and of 100 meters, or 328 feet at the top; and that the channel from the Bitter Lakes to the Mediterranean should be cut to a width of 44 meters, or 144 feet, at the bottom; and 80 meters, or 262 feet, at the water-line. In addition to this liberal allowance of width, provision was also made for sidings, excavated at equal distances along the line of the canal as at present. The construction of the canal had made but little progress when it was found that its cost had been altogether under-estimated, and consequently the width of the cross-sections was made to tally with the amount of money available, thereby enabling the skillful and plucky "*Fondateur*," M. de Lesseps, to announce to the world in the month of November, 1869, that his great enterprise was practically a *fait accompli*. The narrowing of the navigable channel by one-half compelled the adoption of the single line, or block system, of passing vessels from sea to sea, and it should not be forgotten, in lamenting over the consequences of an insufficient area of cross-section, that by the slow but safe mode of transit that had been unavoidably adopted up to this time, not only had serious collisions between ships in motion been avoided, but that where the currents were strong—and they frequently attained a velocity of 2½ knots an hour between Suez and the Bitter Lakes—the re-floating of vessels, which so often got aground by defective steering, and were driven athwart the channel by the wind or currents, was a much easier operation than if the canal had been cut to the width at first intended. As this was not the place to discuss the merits or demerits of the plans proposed for widening the existing canal, or for the construction of a second one across the Isthmus of Suez, he would only observe, in conclusion, and with regard to canals generally, that according to his long experience in the navigation of confined waterways, the acquirement of extra depth was of more importance even than that of additional width, where greater speed was required; for the reason that when the keel of a vessel was near the bottom, or, as sailors said, she began "to smell the ground," her speed, irrespective of other causes, was very considerably diminished, and her steering qualities became so much impaired as to make her very difficult to handle, even when she had her head to the current and her progress was not baffled by the wind.

MODERN BRONZE ALLOYS FOR ENGINEERING PURPOSES.*

By PERRY F. NURSEY, C. E.

From "Iron."

In order to mark the progressive steps of man, his early history has been divided into three periods, each being named after the materials chiefly used in them for supplying him with weapons, tools, and ornaments. Thus we have the age of stone, the age of bronze, and the age of iron. To these our own times have added the age of steel, which, of course, simply means a further, but most important, development of the age of iron. It occurs to the author that in like manner a similar development is going on in the present day with respect to bronze. As, however, no generic term has been invented in these very inventive times for

* Paper read before the Society of Engineers, October 6, 1884.

the new variations of that most ancient and useful alloy, he is unable to designate this fifth age by a new title, and so is content to consider it as a revival of the bronze age in a more advanced and more highly developed form. As, however, the age of stone was divided into two parts, namely, the old stone age, when men simply chipped stones, and the newer stone age, when they learned to grind and polish them, so perhaps it may be admissible to consider the present as the newer bronze age. Nor is it altogether inapt so to consider it when we see what a many varieties of bronze have been produced within the last few years possessing very distinctive features from the ancient alloys, and some very remarkable qualities as compared with them, and how very numerous the purposes are to which these varieties are applied, superseding, as they do in many instances, iron, and even steel itself. These considerations, and the knowledge of the great value of these alloys to the engineer and the shipbuilder, have led the author to bring a few facts concerning them before the society in the hope that they may prove interesting and possibly useful to the members.

Although, for the purpose of drawing a fanciful parallel between the past and the present, the author has taken his hearers back to the childhood of the world, when men first mixed and melted copper and tin together, and fashioned in a rude way from the resulting alloy their spear-heads, their hatchets, their ear-rings, and their bracelets, he does not intend to fill up the gap formed by the intervening centuries by following up the gradations by which this alloy was made at length to subserve the highest purposes of art, which, as regards statuary, probably reached a climax during the reign of Alexander the Great. He purposes only to touch upon a few points of metallurgical interest relating to the bronze of the past, and then by a rapid transition to come down to the present, and to enter upon a consideration of the various alloys of the bronze family which the ingenuity of our own day—stimulated, doubtless, by the necessities of the age we live in—has succeeded in rendering available for engineering purposes during the last few years.

Turning then, briefly, to the bronzes of the ancients, we find them varying considerably in the proportions of their two ingredients—for in the main copper and tin only were used—according to the purposes for which they were intended. Thus, modern chemical analysis shows that ancient bronze nails contained 20 of copper to 1 of tin; soft bronze consisted of 9 to 1, medium bronze 8 to 1, hard bronze 7 to 1, and mirrors about 2 to 1. The bronze weapons and tools of the ancients contained from 8 to 15 per cent. of tin. A Roman sword blade found in the Thames showed 85.70 copper and 10.02 tin, whilst another one found in Ireland gave on analysis—copper 91.39 and tin 8.38. The bronze weapons of the Greeks and Romans have been found not only to be of the true composition for insuring the greatest density in the alloy itself, but the cutting edges, by undergoing a process of hammering, were brought up to the highest degree of hardness and tenacity. And here the author would digress for one moment to observe that this is exactly the way in which he has seen the edges put on scythe blades and other cutting tools in Styria, where he has seen some of the finest steel made in the simplest and rudest manner. Returning to the subject of the paper, it is to be observed that most of the ancient coins were of bronze, a small percentage of zinc being added in some cases to improve the color. According to analyses made by Mr. J. A. Phillips, the quantity of tin relatively to copper varied very slightly, even over a range of 300 years. The following are the proportions of copper and tin, the other ingredients being omitted:

Coins.	B.C.	Copper.	Tin.
Alexander the Great.	335	86.72	13 14
Philippus V.....	200	85.15	11.10
Athens.....	—	88.41	9.95
Ptolemy IX.....	70	84.21	15 59
Pompey.....	53	74.11	8 56
The Atilia family....	45	68.72	4 77
Augustus & Agrippa.	30	78.58	12.91

Bronze, pure and simple, consists of a mixture of copper and tin in certain proportions. These proportions, as we have seen, are varied according to the purpose for which the compound is intended. Other metals, moreover, such as zinc, lead, phosphorus, manganese, silicium, and iron, may be, and have been, added without unclassifying the product,

which is still called bronze, provided that copper and tin are the chief contituents. The bronzes of France are known to contain nearly always four metals, namely, copper, tin, lead and zinc. It is also stated that some contain minute and variable quantities of nickel, arsenic, antimony and sulphur. It is the addition to bronze, pure and simple, of certain proportions of one or other of the metallic substances previously referred to that constitutes the modern development of bronze manufacture, and which has given us some of the most useful and at the same time some of the most remarkable alloys known. These comprise no fewer than eleven distinct products, all of which find their uses in connection with the practice of engineering. These are—phosphor bronze, silicium bronze, manganese bronze, delta metal, phosphor copper, phosphor-manganese bronze, phosphor-lead bronze, phosphor tin, aluminium bronze, silveroid, and cobalt bronze. These alloys form the subject for present consideration, and they will be dealt with by the author in the foregoing order. There are other bronzes which are used as substitutes for gold in cheap imitation jewelry; but although they are, in the main, only variations of some of the bronzes with which the author has to deal, their applications are such that their notice does not fall within the scope of the present paper.

Attention was directed some years since to the use of phosphorus in improving the character of bronze for various purposes, and eventually with very successful results. The action of phosphorus on copper alloys is principally due to its reducing qualities, by virtue of which the oxygen absorbed by the molten metal is removed, or rather the oxides thereby produced are eliminated, and there is imparted to the metal that degree of homogeneity, strength and toughness which are peculiar to the chemically pure metal. The phosphorus, by producing these effects is converted into cuprous oxide, which floats on the surface of the molten metal in the shape of a very fluid slag, whilst the superfluous quantity combines with the metal. This being the case, it is not desirable to add to the bronze a larger quantity of phosphorus than will suffice to reduce the oxide present. It is thought by some that the phosphorus itself imparts to the bronze the qualities of hardness and strength, and that, therefore, the more phosphorus put into the metal the better the result as regards hardness. This, however, is not the case, inasmuch as hardness would be obtained at the expense of toughness. The question of producing the various qualities of this class of metal depends not so much upon the quantity of phosphorus as upon the correct proportioning of the various ingredients, phosphorus included. Some of the alloys to which the author will direct attention are formed by the addition of a small proportion of a compound of phosphorus and copper or other metal to the bulk of the copper to be treated. Inasmuch however, as great care is required in determining the exact proportions of the ingredients in making phosphor-bronze alloys, it appears to the author that it would be much safer, and probably much more economical for manufacturing engineers to obtain the alloys ready prepared for the special purpose for which they require them, and which would, other things being equal, obviate all chance of failure by reason of a careless workman adding too little or too much of the phosphorized metal to the bulk.

Phosphor Bronze.

The first of the modern bronzes for notice in the order of time is phosphor bronze, which was invented by Dr. Kunzel, of Blasewitz, Dresden, and was brought into practical use in this country early in 1873 by the Phosphor-Bronze Company, who have from time to time patented several improvements both as regards alloys and methods of manufacture. Phosphor-bronze alloys are composed of copper, tin, phosphorus, and other ingredients in definite proportions, and are made to be either as ductile as copper, as tough as iron, or as hard as steel, accordingly as the proportions of the constituents are varied. The alloys used for rolling and drawing have very different proportions to those employed for castings, for bearings, and parts of machinery. The castings of the metal, owing to its great fluidity when melted, are perfectly sound and homogeneous. Wherever strength, toughness, and durability are desiderata, phosphor bronze is

found to be far better adapted than gun metal and brass, and in many cases than iron and steel. With regard to the applications of phosphor bronze, it may truly be said that their name is legion. This remark applies in the main to most of the modern bronze alloys presently to be described, so that, in order to save repetition, the author will here observe that chief amongst their many applications are the manufacture of wire, rods, tubes, sheets, ornamental castings, screw propellers, pinions, cylinders, valves, bearings, bushes, and other parts of machinery exposed to friction. Phosphor bronze possesses the advantage of not becoming crystalline under the action of repeated shocks and bends, and is therefore well adapted for making wire rope; and as it is not acted on by corrosive liquids, as found in mines, or by the atmosphere, its value as a metal remains constant. It is being used in the shape of sheets for the hulls of torpedo boats and steam launches with satisfactory results. In order to ascertain its resistance to the chemical action of dilute sulphuric acid, two similar sheets of copper and of phosphor bronze were immersed in acid water 10° Beaume strength, and at the temperature of the surrounding atmosphere; after three months it was found that the copper had lost 4.15 per cent., and the phosphor bronze only 2.3 per cent. Phosphor bronze sheet, moreover, stands the action of sea-water much better than copper. In a comparative experiment made at Blackenberghe, lasting over a period of six months, between the best English copper and phosphor bronze, the following results were arrived at. The loss in weight due to the oxidizing action of sea-water averaged for the copper 3.058 per cent., while that of phosphor bronze was but 1.158 per cent.

In making castings from phosphor-bronze alloys, a new or clean plumbago crucible is used, so as to avoid any admixture of other metals, and some charcoal or coke is kept on the metal during the melting to prevent oxidation. For large castings the moulds are thoroughly dried and dressed with a mixture of black-lead and water. Small work is cast green. In order to avoid segregation, it is necessary to pour phosphor-bronze alloys only just before the setting takes place. This is accomplished by cooling the molten metal by putting in ingots or runners, and when the metal no longer melts these, but adheres to them it is a sign that the pouring should take place. Previously to pouring, the molten mass is well stirred by means of an iron rod covered with a paste of either fireclay or plumbago. Besides the original phosphor bronze with which the author has dealt so far, the Phosphor-Bronze Company a year or two ago brought out two other varieties. These were the outcome of an endeavor on the part of the company to meet as far as practicable the various requirements of engineers and millwrights, particularly in connection with parts of machinery exposed to combined friction and pressure. By slightly changing the proportions of the component parts of some of the ordinary mixtures, new alloys having very valuable and distinct characteristics have been produced, and which have been practically tried and proved. These new alloys are known as phosphor-bronze duro A, and phosphor-bronze duro B. Duro A is a very dense metal, adapted for all bearings carrying heavy wheels running at great velocities, and generally for all quick-speed purposes. Duro B is intended for the bearings of hot-neck rolls, and for all bearings having to withstand great pressure, such as plate and sheet roll bearings, and for general engine purposes.

Having referred to the great durability of phosphor bronze under conditions of work, the author will here notice one instance out of several which have been brought under his notice from time to time. About two years since he inspected a pair of slide valves, which had been then recently taken out of one of the North-Eastern Railway Company's express engines after six and a-half years' working, during which the engine had run 261,182 miles between Newcastle and Edinburgh. They were taken out to replace the cylinders with a pair of a different type.

The engine was of the following dimensions: Cylinders, 17 inches diameter by 24 inches stroke; four coupled wheels, 7 feet diameter; working pressure 140 lbs. per square inch; weight of engine in working trim, 39 tons 16 cwt.; weight of tender, 26 tons 4 cwt.

Mr. Fletcher, the assistant locomotive superintendent of the North-Eastern Railway, states that the slides, in the six and a-half years, had only worn down to the thickness at which they generally took out gun-metal slides, and that, had it not been that they were putting in a pair of cylinders of different type, he would certainly have let them run longer, as he considered them quite safe, taking into consideration the great superiority of phosphor bronze over gun metal. The original thickness of these slides was 1 inch, and they were worn down to $\frac{5}{8}$ inch thick. Gun-metal slides rarely exceed eight months' work when they are worn out. The cylinder faces were in excellent condition, the wearing being, as it should be, on the valves.

Tables I. and II. give the results of some comparative experiments made by Mr. David Kirkaldy with phosphor bronze and various other alloys and metals, whilst Table III. gives the results of tests made with axle bearings of various metals.

Silicium Bronze.

We come, in the next place, to silicium bronze, which, in some respects, may be considered as an outcome of phosphor bronze, although its invention is not due to Dr. Kunzel, who died some years ago. The inventor is M. Lazare Weiller, of Angouleme, who exhibited phosphor-bronze telegraphic and telephonic conductors at the Paris Electrical Exhibition of 1881, where the author first saw them, and where they were novelties. M. Weiller carried out an exhaustive series of experiments with this wire, the results of which went to show that it possessed a conductivity one-third that of copper, but $2\frac{1}{2}$ times that of iron and steel. Phosphor-bronze wires, therefore, proved very useful for telephonic communication, but not for telegraphic purposes, where higher conductivity is required. M. Weiller, therefore, set himself the task of discovering a material analogous to phosphor bronze, and his labors were at length crowned with success by the discovery of silicium bronze. In this alloy the phosphorus is replaced by a silicious metalloid which produces a better conductor than does phosphorus. M. Weiller thus obtains a wire presenting the same resistance to rupture as phosphor-bronze wire, but with a much higher degree of conduc-

Table I.—Results of Experiments to Ascertain the Elastic and Ultimate Tensile Strength of Twelve Pieces of Phosphor-Bronze, Six Pieces of Ordinary Bronze, and One Piece of Brass.

Description.	Stress.		Ratio of Elastic to Ultimate.	Contraction of Area at Fracture.	Extension Sets at	
	Elastic per Square Inch.	Ultimate per Square Inch.			Lbs. 20,000 per Sq. Inch.	Ultimate.
	Lbs.	Lbs.	Per cent.	Per cent.	Per cent.	Per cent.
Phosphor-bronze..	23,800	40,876	58.2	3.9	0.40	3.8
" " ..	21,900	49,865	43.9	9.8	0.09	10.6
" " ..	19,800	33,623	58.9	5.9	0.18	4.6
" " ..	15,400	24,193	63.6	7.9	1.94	6.7
" " ..	14,900	21,755	68.5	5.9	2.26	4.3
" " ..	13,700	25,715	53.3	9.8	3.12	10.9
" " ..	21,400	35,024	61.1	5.0	0.11	3.6
" " ..	19,200	43,032	44.6	15.1	0.26	14.1
" " ..	16,100	44,448	36.2	31.9	0.98	33.4
" " ..	13,400	36,044	37.2	19.9	1.52	16.5
" " ..	11,800	24,988	47.2	13.4	5.13	11.1
" " ..	10,700	34,024	31.5	23.0	3.06	17.4
Ordinary " ..	19,700	29,534	66.7	8.4	0.18	4.0
" " ..	19,600	27,376	71.6	5.0	0.18	2.6
" " ..	17,800	22,592	78.7	5.0	0.72	2.3
" " ..	17,700	21,946	80.7	3.3	0.50	1.6
" " ..	17,600	20,482	85.9	1.5	0.68	1.2
" " ..	16,400	20,296	80.8	3.3	1.10	1.7
Brass.....	10,100	27,518	36.7	18.3	5.80	16.1

LE II.—RESULTS OF EXPERIMENTS TO ASCERTAIN THE TENSILE STRENGTH AND THE RESISTANCE TO TORSION OF VARIOUS WIRES.

Description.	Pulling Stress. Wires as Drawn.				Twists in 5 Inches.	
	Diameter.	Area.	Stress.		As Drawn	Annealed.
			Total.	Per Sq. In.	Mean of 3.	Mean of 3.
	Inch.	Sq. Inch.	Lbs.	Lbs.	Twists.	Twists.
Phosphor bronze	0.0655	0.003367	340	100,980	5.0	91
" "	0.0640	0.003216	389	120,957	22.3	52
" "	0.0600	0.002827	352	124,313	7.0	87
" "	0.0610	0.002922	379	129,705	8.3	98
" "	9.0595	0.002778	336	120,950	13.0	124
" "	0.0585	0.002655	395	147,113	7.5	97
" "	0.0640	0.003216	513	159,515	13.3	66
Copper	0.0640	0.003216	203	63,122	86.7	96
Brass	0.0605	0.002871	233	81,156	14.7	57
Steel (ordinary)	0.0600	0.002827	342	120,976	22.4	79
Iron, galvanized, best best C	0.0580	0.002643	170	64,321	26.0	44
" " best charcoal E.	0.0580	0.002643	174	65,834	48.0	87

TABLE III.—RESULTS OBTAINED WITH VARIOUS AXLE BEARINGS.

Kind of Bearing.	Composition in 100 Parts Alloy.	Comparative Cost of 100 Kilos. Bearings inclusive of Melting Expenses, Loss, &c.	1 Kilo. Bearing Metal Runs			Cost of Bearing Metal per Wagon with 4 Bearings per 100 Kilometers.	Name of Railroad where used.
			German Miles.	Kilometers.	Wear per 100 Kilos. for 4 Bearings.		
		Marks.			Grammes	s. gr.	
Gun metal	83 copper, 17 tin.	260.20	12,052	90,390	11.60	0.301	Austrian Railway
"	82 " 18 "	260.80	13,320	99,900	10.01	0.260	Gr. Cent. Belge.
White metal	3 copper, 90 tin, 7 antimony.	298.68	9,104	78,280	14.64	0.395	Austrian Railway
"	5 copper, 85 tin, 10 antimony.	293.40	11,750	88,145	11.35	0.331	Niederschlesisch-Markische Bahn.
Lead composition	84 lead, 16 antimony	118.56	10,338	81,280	12.30	0.145	Austrian Railway
Phosp'r bronze	—	360	57,226	429,200	2 33	0.081	Gr. Cent'l Belge.
Gun metal on brake cars	82 copper. 18 tin.	260.80	1,218	9,134	109.48	2.844	" "
Phosp'r bronze on brake cars	—	350	14,320	107,410	9.31	0.325	" "

tivity, rendering it applicable for telegraph lines, and bringing the valuable qualities of lightness and non-oxidizability within easy and economical reach. In a paper upon electrical conductors, read by Mr. W. H. Preece, F. R. S., before the Institution of Civil Engineers, in December, 1883, that gentleman observed, in reference to phosphor and silicium bronze wires, that in their manufacture phosphorus and silicium had the property of removing impurities, particularly the oxides, though doubtless some of the flux remained. Phosphorus had a most injurious influence on the electrical resistance of the alloy. Silicium was far superior; hence the silicium bronze was preferable for telegraphic purposes.

Its efficiency was very great: in fact, phosphor bronze had disappeared for telegraph wire, and had been replaced by silicium bronze. It is important to note that the properties of this alloy are such that, although the wires are only one-tenth as heavy as the ordinary wires, they are of equal strength. Moreover, it is affirmed that, if broken, they will not fall to the ground as the ordinary wires do, but by reason of their high elasticity, they will spring back and coil up close to the standards. The author should mention that M. Weiller has associated himself with the Phosphor Bronze Company, who are manufacturing silicium-bronze wire, which, the author is informed, has come largely into use for overhead telephone lines, and proves a satisfactory substitute for the cumbrous iron wire. Table IV. shows the relative strength, resistance, and conductivity of various wires.

TABLE IV.

Description of Wire.	Tensile Strength per Square Inch in Tons.	Resistance per Mile in Ohms.	Relative Conductivity.
Pure copper	17.78	33.2	100
Silicium bronze (telegraph)	28.57	34.5	96
Silicium bronze (telephone)	48.25	103	34
Phosphor bronze (telephone)	45.71	124	26
Swedish galvanized iron	22.86	216	16
Galvanized Bessemer steel	25.40	249	13
Siemens-Martin steel	26.67	266	12

MANGANESE BRONZE.

The author now comes to that class of bronzes into the composition of which iron in one form or other enters, and of which there are two principal varieties, namely, manganese bronze and delta metal. It is stated that some of the ancient bronzes have been found on analysis to contain a small percentage of iron, but it does not appear that any traces of manganese have ever been discovered. It is thought probable that the ancients knew that the addition of iron to bronze would increase its hardness, and introduced it for that purpose. Modern inventors have proposed combinations of iron with brass alloy, and some have also introduced manganese by reducing the black oxide of manganese and combining it with the copper. Until a comparatively recent date, however, none of these alloys appears to have been brought into permanent practical use. More than a hundred years since James Kier proposed an alloy of 10 parts of iron with 100 parts of copper and 75 parts of zinc, and in later times Sir John Anderson, when superintendent of Royal Gun Factories, carried out a number of experiments with similar alloys, and with some very good results, but none of them appear to have been brought into practical use. The addition of iron unquestionably increases the strength and hardness of these alloys, but, according to some experiments made by Mr. P. M. Parsons, they would appear to acquire these qualities at the expense of ductility and toughness, and it is probably on this account that this class of alloys had not come into general use up to the time of Mr. Parsons' experiments. Mr. Alexander Parkes and the late Mr. J. D. Morries Stirling, both eminent metallurgists, appear to have been the first to propose and carry into practice the use of manganese. Mr. Parkes combined manganese alone with copper, and used this alloy to form improved alloys of brass and yellow metal, of which to make sheathing, rods, wire, nails, and tubes.

Mr. Stirling in 1848 proposed to use manganese in various brass alloys in which iron was present. At first he combined about 7 per cent. of iron with the zinc, and added to the copper a small percentage of manganese, by reducing the black oxide of manganese with the copper, in the presence of carbonaceous materials, and then added to it the requisite quantity of the iron and zinc alloy to make the improved brass required. Mr. Stirling's idea was to combine the iron with the zinc by fusion, but in practice he found a more ready means of procuring

the zinc and iron alloy by employing the deposit found at the bottom of the tanks for containing the melted zinc for galvanizing iron articles. This product consists of zinc with from 4 to 6 per cent. of iron, but this percentage is very variable, and the results of its use, therefore, in some cases unreliable. The author is informed that metal made by this process was in use for sometime for carriage bearings, on the London and North-Western and other railways, with very good results; but it has long since been superseded, and does not appear to have ever been introduced for any purposes where the requirements were great strength, hardness, and ductility.

The time, however, arrived, namely, in 1876, when these requirements were met by the aid of manganese in the manganese bronze of Mr. P. M. Parsons. This alloy is prepared by mixing a small proportion of ferro-manganese with copper, and which is afterwards made into alloys similar to gun metal, bronze, brass, or any other alloy of which copper forms the base. The ferro-manganese is melted in a separate crucible, and is added to the copper when in a melted state. The effect of this combination is similar to that produced by the addition of ferro-manganese to the decarburized iron in a Bessemer converter. The manganese in a metallic state, having a great affinity for oxygen, cleanses the copper of any oxides it may contain, by combining with them and rising to the surface, in the form of slag, which renders the metal dense and homogeneous, as already explained by the author in respect of phosphorus. According to Mr. Parsons, a portion of the manganese is utilized in this manner, and the remainder, with the iron, becomes permanently combined with the copper, and plays an important part in improving and modifying the quality of the bronze and brass alloys, afterwards prepared from the copper thus treated. The effect is greatly to increase their strength, hardness, and toughness, the degrees of all of which can be modified, according to the quantity of the ferro-manganese used, and the proportions of the iron and manganese it contains.

It will thus be seen that Mr. Parsons' method of making manganese bronze is altogether different, both in principle and effect, from the inventions of either Parkes or Stirling. Stirling's method of combining the iron with the zinc, in order to introduce it into the alloys, precludes its use in any but those alloys in which a considerable portion of zinc is employed, such as brass or yellow metal. It could not be applied to any of those important alloys, of the nature of gun metal or bronze, in which copper and tin are the chief ingredients. An equally important difference in the manufacture of manganese bronze consists in adding the manganese in its metallic state, in the form of ferro-manganese, to the copper, by which the copper is cleansed from oxides, which it cannot be when the manganese is reduced from the black oxide and combined with the copper by one and the same operation, as was done by Parkes and Stirling. Another point of importance is the great nicety with which both the iron and manganese can be adjusted, and their effect controlled by adding the ferro-manganese to the copper, as pursued in the manufacture of manganese bronze. The amount of manganese required for deoxidizing the copper, and for permanent combination with it, being well known by experience, it is found that very slight variations in quantity have a perceptible and ascertained effect in modifying the qualities of the alloys produced. The toughness can be increased, and the hardness diminished, or vice versa, at will, precisely as is done in the manufacture of steel, by increasing or diminishing the percentage of carbon and manganese. In preparing the ferro-manganese for use, Mr. Parsons prefers that which is rich in manganese, containing from 50 to 60 per cent. This is melted with a certain proportion of the best wrought-iron scrap, so as to bring down the manganese to the various proportions required. At the same time any silicon it contains is reduced and the metal refined. About four qualities of ferro-manganese are made in practice, containing from about 10 to 40 per cent. of metallic manganese. The lower qualities are used for those copper alloys in which the zinc exceeds the tin, and the higher qualities for those in which tin is used alone, or exceeds the zinc used in combination; and the amount of ferro-manganese added varies generally from about 2 to 4 per cent. After a number of careful experiments and crucial tests, the Manganese Bronze and Brass Company, who are the

sole manufacturers of manganese bronze, adopted the manufacture of five different qualities of this alloy, although other varieties can be produced for special purposes. In No. 1 quality the zinc alloyed with the copper is considerably in excess of the tin. It is cast into ingots in metal moulds, and then forged, rolled, or worked hot, and made into rods, plates, sheets, sheathing, and it may also be worked cold, and drawn into tubes and wire. When simply cast, it is stated to possess a tensile strength of about 24 tons per square inch, with an elastic limit of from 14 to 15 tons. When rolled into rods or plates, it has a tensile strength of from 28 to 32 tons, with a limit of 15 to 23 tons per square inch, and it stretches from 20 to 45 per cent. of its length before breaking. When rolled cold, the elastic limit rises to over 30 tons, and the breaking strength to about 40 tons, and it still elongates about 12 per cent. before breaking.

Manganese bronze No. 2 is similar to No. 1, but stronger, and it can be cast in sand for special purposes where strength, hardness, and toughness are required. But it must be melted in crucibles, as passing it through the reverberatory furnace injures the metal, and causes unsound castings. It is not, therefore, adapted for general brassfounders' purposes. One of the most important applications of this quality is that of producing articles cast in metal moulds under pressure. Blocks of this metal thus simply cast are said to have all the characteristics of forged steel as regards strength, toughness, and hardness, without any of its defects. It is perfectly homogeneous, and while not possessing a fibrous texture derived from rolling or hammering, it is still fibrous in character, and this in not one but in all directions alike, and, when broken, shows a beautiful silky fracture. Its tensile strength is from 32 tons to 35 tons per square inch, and its elastic limit from 16 to 22 tons, with an ultimate elongation of from 12 to 22 per cent.

Another feature of No. 2 quality is that it can be cast on to any object, and will shrink on to it with a force equal to its elastic limit, and when released, will show an amount of resilience of about double that of steel. As an instance of this, the author is informed that a hoop of this manganese bronze, shrunk on to a solid cylinder of iron, stretched, when hot, 0.03 of its diameter in the process of contraction, and, when cold and released, sprang back about 0.003 of its diameter. As regards hardness, it is about equal to mild steel.

In order to ascertain its efficiency in this respect, and to compare it with gun metal, wrought iron, and steel, a knife-edged angular die was forced into the flat surface of a piece of each of these metals, and of the No. 2 manganese bronze cast under pressure. In order to produce an indentation of equal depth in each of these specimens, the following pressures are required:

	Cwt.
Gun metal	12
Wrought iron	15
Mild steel	20
" "	25
Manganese bronze as cast	20
" " hardened by pressure	22–23

These results point to this material as the most suitable for the construction of hydraulic and other cylinders required to stand great strains and possibly for ordnance. No. 3 quality is composed principally of copper and tin in about the same proportions as gun metal, combined with a large percentage of ferro-manganese. Its chief characteristics are great transverse strength, toughness, and hardness, the facility with which it can be cast, and the soundness and uniformity of the castings produced. It will stand melting in an ordinary reverberatory furnace without injury to the metal, which is a point of importance in producing large castings. The author is informed that a bar of this metal cast in sand in the ordinary way, 1 inch square, placed on supports 12 inches apart, requires upwards of 4,200 lbs. to break it, and before breaking it will bend to a right angle, and it will sustain from 1,700 to 1,800 lbs. before taking a permanent set. This quality of manganese bronze is used for wheel gearing, supports and connections of machines, crank pin brasses, the shells of main and other bearings of marine and other engines, axle boxes, and other parts of locomotive engines. It is also adapted for statuary and art purposes generally, as well as for large bells.

The most important application of this quality of manganese bronze from a com-

mercial point of view would appear to be that of screw propellers. Owing to the great strength of this quality of the metal, and its non-liability to corrosion, propeller blades can be made thinner than even those of steel. Their surfaces are very smooth, and, when cast, they are said to be theoretically true to form, whereas, with steel propellers, allowance has to be made against the corrosion which takes place, and their deficiency in toughness, by increasing their thickness, and their form is liable to become distorted in the annealing oven they have to pass through after being cast. The author is informed that it has been proved conclusively by the logs of steamships which have had their steel propellers replaced by manganese-bronze blades that their speed has been increased, and the consumption of coal diminished, whilst the vibration and strain on the ship and machinery have been reduced.

The commercial bearing of the question alluded to by the author is, that these advantages are secured at a considerably less ultimate cost than by the use of steel, taking it upon the average life of a vessel; for although the first cost of a propeller with manganese bronze blades is double that of steel, it is said to be practically indestructible, whereas, at the end of about three years steel blades become so corroded that they have to be renewed, which brings up the total cost of the steel blades on an average to two or three times those of manganese bronze. That these propellers are incorrodible, and in every other respect efficient, is said to be proved by experience, as some have been at work for nearly four years, and are as perfect as when first applied.

The soundness and tenacity of the No. 3 quality of manganese bronze thus applied was demonstrated by an accident which occured to the propeller of the *Garth Castle*, on its launch from the yard of Messrs. John Elder & Co., in 1880. One of the blades came in contact with the jetty, and was bent round without a crack to nearly a right angle, and was afterwards hammered back cold to its original form without detriment. Another example is afforded by the propeller of the North German Lloyd's steamship *Mosel*, which was wrecked. One of the propeller blades after it was recovered from the wreck, was found to be completely doubled over, thus affording an idea of the tenacity of the metal.

With regard to the Nos. 4 and 5 qualities of manganese bronze, the author has only to observe that they have no particular claim to strength, but are effectively used for bearings, slide valves, slide blocks, piston rings, and, in fact, wherever friction occurs.

Table V. shows the results of some tensile tests applied to eleven specimens of manganese bronze. The tests in the first series were made at the Royal Gun Factories, and at University College, London, respectively. Those in the second series were made at the Royal Gun Factories, whilst those in the third series were made by the Manganese-Bronze Company. The specimens tested at the Royal Gun Factories were 2 inches in length, whilst those tested at University College, and by the company, were 8 inches in length. It is to be observed with reference to the last two samples that No. 10 was cut from the side of the ingot, whilst No. 11 was taken from the center. The ingot shows a higher quality on its exterior, which indicates its suitability for guns, where the interior would be bored away. The Manganese-Bronze Company are, in fact, now making some castings for artillery.

Delta Metal.

The second and latest example of the successful addition of iron to bronze is afforded by delta metal, which was brought out by Mr. Alexander Dick in 1883. And here it may be as well if the author explains how this alloy came to receive its name. He does so because it was one of the first inquiries he addressed to the inventor, and because he has several times been asked the question, and if the invention had any reference to the delta of rivers. The author need hardly say that it has no such reference. The name "delta" was given to it by Mr. Dick simply for the purpose of connecting it with his own name, delta being the Greek for the letter D, the initial of the inventor's surname. In his researches and early experiments, and, in fact, in the development of delta metal into practical form, Mr. Dick was influenced by the circumstance that some twenty years since Aich and Baron Rosthorn, of Vienna, intro-

TABLE V.—TESTS OF MANGANESE BRONZE BY TENSILE STRAIN.

No.	Description.	Where tested.	Elastic Limit.	Breaking Strain.	Ultimate Elongation.	Remarks.
			Tons ₱ □″	Tons ₱ □″	Per cent.	
1	No. 1 rods rolled hot.	R. G. F.	11.00	29.00	44.6	Mild, annealed for riveting cold.
2		U. C. L.	13.17	29.29	33.4	Annealed.
3		Do.	23.54	31.60	26.5	As delivered from the rolls.
4		Do.	24.32	31.43	23.3	
5		R. G. F	34.40	39.60	11.6	Ditto, and finished cold.
6	No. 1 plates rolled hot	R. G. F.	14.06	28.46	23.2	Pulled across fiber. (Annealed)
7		Do.	14.06	30.13	47.8	Pulled with fiber. (Annealed)
8		Do.	14.80	30.78	34.1	Pulled across fiber. (Annealed)
9		Do.	16.70	30.10	28.8	Pulled with fiber. (Annealed)
10	No. 2 cast under pressure	M.B. & B Co.	18.00	35.00	22.0	Cast an iron cylinder and pressed while liquid.
11		Do.	16.23	31.90	12.4	

No. 10 cut from side of ingot, and No. 11 from center.

duced a small percentage of iron into copper-zinc alloys, with the view of improving the same. The results obtained, which are tabulated by Dr. Percy in his work on *Iron and Steel*, show that the alloys possessed very remarkable strength and tenacity, and it seemed strange to Mr. Dick that, having such valuable qualities, they did not come into general use. A London brassfounder, who used to manufacture these alloys, informed Mr. Dick that at times he obtained excellent results with bearings and other parts of machinery made therewith, and then again the results were the very reverse, in spite of his taking the greatest care in manufacturing, as he thought, in identically the same way. Unable to account for the different results, he and several other manufacturers were obliged to abandon these alloys in spite of their promising features.

Mr. Dick endeavored to ascertain the cause of the uncertainty of these results, and he produced various quantities of the alloy, apparently in exactly the same way, by dissolving wrought iron in molten copper according to the Austrian method. The qualities of the resulting alloys, however, varied very much, simply because the amount of iron dissolved varied in each parcel. His first object, therefore, was to find a method by which he was enabled to introduce a known and definite quantity of iron, which he succeeded in doing by dissolving the iron in molten zinc to saturation, and adding the same, with or without pure zinc, to the molten copper. The desired quantity of iron can be introduced with great nicety. In consequence of the metals partly oxidizing during the process of remelting, the castings, however, again varied in character, the oxides being dissolved in the alloy and destroying its tenacity and strength. This second difficulty was overcome by adding a small percentage of phosphorus in combination with copper. In some cases Mr. Dick also introduces tin, manganese, or lead into the alloy, to impart special qualities to it. By a series of experiments the most useful combinations were then ascertained, and alloys of definite compositions, and possessing special and very valuable qualities, are now produced under the name of delta metal.

The specific gravity of delta metal is 8.4, its melting point 1800°. In color it resembles gold alloyed with silver. It can be worked hot and cold. When melted, it runs freely, and the castings produced from it are sound and of a fine close grain. Like all copper alloys, it does not weld, but can be brazed like copper or brass, and if the object is of sufficient thickness, it can be "burned" with great facility. Cast in sand, it has a breaking strain of over 21 tons per square inch. When forged at a dark red heat, the breaking strain is raised to from 33 to 35 tons, and when hammered or rolled cold, it will stand a strain of more than 40 tons per square inch. The varieties destined for working cold can be drawn into tubes and wire, or rolled into sheets

and rods, whilst those intended for working hot not only can be rolled with great facility when heated to about 1600° Fahr., but are also capable of being stamped or punched, similarly to wrought iron and steel, into a great variety of articles which have hitherto been cast in bronze or brass. The author would draw special attention to this quality of delta metal, as the possibility of hot stamping offers great advantages over castings—the articles are turned out much cheaper, they are of perfect soundness, and possess three times the strength of brass castings. Blowholes, which frequently can only be detected after expending time and labor, are impossible, besides which a great saving is effected in the finishing of such articles, as, unlike castings, the stampings leave the die almost perfect, requiring little or no tooling, but ready to be polished. Experiments are being made at the present time to utilize the semi-plastic state of heated delta metal to press it by hydraulic pressure into tubes and rods of round, hexagonal, and other sections in a way similar to that in which lead tubes are pressed.

It is interesting to know that the iron introduced by Mr. Dick's process is really chemically combined. This is proved by the alloy not rusting when exposed to the moist atmosphere, and also by its having no influence whatever on the magnetic needle. Experiments have shown that by suspending a piece of delta metal on a thread, and at various angles between the ends of a powerful electro-magnet, no oscillations of the suspended metal could be observed, which evidently proved that the iron contained therein had lost its magnetic properties.

The uses to which delta metal can be applied are very numerous. It is said to replace the best brass and gun metal with advantage, and in many instances iron and steel also, as it does not corrode or rust. Thus parts of rifles, of guns, of torpedoes, tools for gunpowder mills, parts of bicycles, gongs, and a number of domestic articles, are now stamped in delta instead of steel; while spindles for steam and water valves, plungers, and pump-rods are forged in the same metal. In the International Exhibition at the Crystal Palace may be seen a steam launch constructed throughout of delta metal by Messrs. A. F. Yarrow & Co. This launch is 36 feet long over all, with a beam of 5 feet 6 inches, and a depth from gunwale to keel of 3 feet. Delta metal having been proved by experiment to be equal in strength, ductility, and toughness to mild steel, the plates and angle pieces of the launch are of the same scantling as they would be if steel were used, viz. $\frac{3}{16}$ inch thick. The stern, keel, and sternposts are of forged delta metal, and scraped together as is usually done. The angle frames are made of the same material, but are placed longitudinally instead of transversely, by which means greater longitudinal strength is secured. The propeller, which is cast in delta metal, is four-bladed, 2 feet 4 inches in diameter, and 3 feet pitch. The engine is of the usual direct-acting inverted type, of sufficient power to develop a speed of from 8 to 9 knots per hour. The superiority which delta metal possesses over steel and iron for shipbuilding is that it does not rust like they do. Such launches are specially adapted for the transport of salt, sugar, and chemicals, which rapidly corrode steel. The extra first cost would probably be quickly repaid, besides which the metal always retains it value.

From further experiments it was found that the elastic limit of delta metal is 31,571 lbs., or 14.1 tons per square inch. The commencement of permanent set took place at 49,757 lbs. equal to 22.2 tons per square inch. The breaking strain per square inch was 80,658 lbs., equal to 37.34 tons; the elongation was 12.9 per cent., and the contraction of area of fracture 17.4 per cent. The crushing test, with a stress of 22,000 lbs., gave 0.80 per cent. of compression; 44,000 lbs., 1.33 per cent.; 66,000 lbs., 2.03 per cent.; 77,000 lbs., 2.71 per cent.; 88,000 lbs., 3.87 per cent.; 99,000 lbs., 5.77 per cent.; 110,000 lbs., 8.20 per cent; 121,000 lbs., 10.76 per cent.; and 132,000 lbs., 13.41 per cent. The ultimate or crushing stress per square inch was 135,700 lbs., equal to 60.5 tons. In the torsional tests the sample was 10 inches long, and it will be seen that it was twisted more than twice round, the torsion being registered in degrees. The chain tested was a portion of one of those supplied to the Brazilian armor-clad turret-ship Riahuelo. The length tested was 10 feet, the links being 0.733 inch in diameter, and the length

giving way under a stress equal to 19.3 tons per square inch.

Phosphor Copper.

We have now done with the modern bronzes of what the author may call the primary series, and have reached those which may be considered as forming a secondary series, in the sense that several of them are more or less but modifications, combinations, or adaptations of those previously described. The author has already referred to the beneficial effect of phosphorus on copper and its alloys, and which consists in producing a material of absolute closeness, of the highest possible degree of toughness and elasticity, or, according to the percentage of phosphorus added, the metal can be rendered soft, or as hard as steel. These excellent qualities must not be attributed alone to the phosphorus in the metal, or only in a secondary degree, but are owing chiefly to the absence of oxygen, which, by the energetic reducing action of the phosphorus, is entirely eliminated. This question having received the attention of Mr. W. G. Otto, of Darmstadt, that gentleman conceived the idea of introducing phosphorus into copper in order to facilitate the work of engineers and founders by enabling them to add a certain proportion of phosphor copper to a given bulk of metal, so as to obtain a phosphor bronze suitable for various purposes. Phosphor copper contains from 15 to 16 per cent. of phosphorus, and Mr. Otto, who is represented in England by Mr. G. Hartmann, applies this product to the purposes of producing phosphor-bronze, homogeneous copper castings, and copper alloys of all classes. In practice the copper is melted in the ordinary way as rapidly as possible, and is kept covered with charcoal. After the requisite quantity of tin, zinc, &c., has been added to the liquid metal—or if remelting old or scrap metal, after these have been completely melted—the crucible is taken out of the furnace and the metal carefully freed from the charcoal, &c., floating on the top, after which the small quantity of phosphor copper necessary is added whilst thoroughly stirring the metal. A skin which is found covering the liquid metal (bronzes in particular) then disappears, and the metal assumes a perfectly bright surface, which is a sign that the quantity of phosphor copper added was sufficient to remove all oxides present. The metal is then cast at once, care being taken to prevent foreign substances and any skin which may meanwhile have formed again from being poured into the moulds. The presence of a perfectly bright surface is absolutely necessary, and also careful stirring of the metal down to the bottom of the crucible, for which purpose Mr. Otto makes special stirrers. With regard to the proportions to be observed, the author is informed that for producing phosphor bronze and remelting old gun metal an addition of from 10 to 12 ozs. of phosphor copper containing 15 per cent. of phosphorus per 100 lbs. of metal is generally sufficient, whilst for making and remelting brass and brass scrap an addition of only 5 to 7 ozs. of phosphor copper is required per 100 lbs. of metal. The author understands that Otto's phosphor copper is in use at many continental government works, as well as by foreign railway companies and at private works, with every satisfaction. Without for one moment wishing to appear as questioning this, the author still adheres to the opinion already expressed, namely, that to purchase the ingots of metal already prepared for the various required purposes by those whose sole business it is to produce them, and whose credit is at stake if an error of proportion be committed, is to his mind the more satisfactory course. He conceives it to be pitting rule of thumb against careful research and practical experience.

Phosphor-Manganese Bronze.

There is in the market a compound known as phosphor-manganese bronze, which is stated to be used for engineering purposes. The author has twice written to the producers of this alloy for information respecting its nature and uses, but without receiving a reply to either of his letters. It is, therefore, the manufacturers' misfortune, and not the author's fault, that this production is not described in the present paper. Silence, however, is said to be golden, and, looking at the compound name of the alloy in question, the adage may apply with special force in the present instance.

Phosphor-Lead Bronze.

About the middle of the year 1881 a

new alloy under the name of phosphor-lead bronze was brought to the author's notice. It was stated to be specially adapted for all purposes where gun metal, brass, or other material is used in the construction of those portions of machinery subject to constant wear or continuous friction. The introduction of lead into its composition, and its homogeneousness, were said to give it special properties, rendering it most efficacious for the purpose mentioned. It had been subjected to every test that experience could suggest, and was reported to have passed them all most satisfactorily. The advantages claimed for phosphor-lead bronze were self-lubrication, greater wearing capacity than any other metal or alloy, great tensile strength—combined with extreme hardness—and non-liability to fracture. It was averred that it remained perfectly cool under continuous and excessive friction, and it was said to be in extensive use on the Continent by manufacturing engineers, shipbuilders, and others with satisfactory results. It was being introduced into this country by Messrs. H. H. Kuhne & Co., of Lobtau, near Dresden; but the author has not heard anything further of this alloy.

Phosphor Tin.

Under the name of phosphor tin, Messrs. Billington & Newton manufacture a compound which is used for making phosphor bronze. This compound is a mixture of phosporus with tin in certain proportions, the metal being sold to consumers who make their own phosphor bronze by adding the phosphor tin to copper. The copper is melted in a crucible, and when in a fluid state, the phosphor tin is added in the same way as ordinary tin. The mixture is then well stirred with an iron rod, covered with a coating of blacklead. The metal is poured just before it begins to set in the crucible, and the moulds are always to be very dry, and where 20 per cent. of phosphor tin is used, the castings are made in chills if possible. The author has applied to the manufacturers for detail particulars and tests, but he has not been favored with them. It will be seen that phosphor tin is used in the same way as the phosphor copper, already referred to, and although the use of phosphor tin is stated to be attended with good results, the author can only repeat the opinion already expressed, that, considering what diverse effects a slight variation in proportions appears to bring about, it is better for most purposes to obtain the alloy ready prepared than to trust to workmen for obtaining uniform results. The author is aware that he may be met by the statement that successful results are daily obtained by workmen using these compounds. This is no doubt true so far as it goes, but it is no answer to his assertion that rule of thumb can never hope to compete with scientific exactitude. He could give instances in the metallurgy of iron and steel where rule of thumb principles held out for a long time against the advances of higher science, but to whose dictum they were in course of time compelled to bow.

Aluminium Bronze.

The history of the practical manufacture of aluminium does not extend very far back into the past; in fact, its commencement dates within the limits of the present generation. The three international exhibitions which have been held in Paris since aluminium began to be worked on a commercial scale form so many landmarks of its progress. In 1855 it was met with for the first time in the Palais de l'Industrie in the form of a large bar, and was exhibited as silver produced from clay. In the exposition of 1867 it was to be seen in a more advanced stage, worked up into castings and various kinds of useful and ornamental articles. There also for the first time was seen the alloy alluminium bronze. The Paris exhibition of 1878 witnessed the maturity of the aluminium manufacture and its establishment as a current industry, having a regular demand and supply for certain purposes within the limits permitted by its somewhat high price. To France, then, is due the merit of having been the first country to carry out Wohler's process for the production of this metal on a commercial scale, and to have created the aluminium manufacture. Until recently, moreover, France appeared to be the only country in which the trade was able to prosper. The English manufactory established at Washington, near Newcastle-on-Tyne, by Messrs. Bell & Co., did not answer, and was closed some ten years ago. The German factory started

at Berlin, by Messrs. Wirtz & Co., hardly lived at all, having drooped before it was well started. In France, however, the manufacture appears to have gone steadily on from the first.

The chief obstacle which has retarded the development of the manufacture of aluminium in England appears to have been the difficulty of obtaining the metal pure, the least portion of foreign matter rendering it useless for the purpose of alloy. This circumstance, coupled with its high price, has caused its use to be very limited, although the value of aluminium alloys has long been well understood. About two years since, however, Mr. James Webster perfected his invention for producing aluminium, and which is now being practically worked. It is claimed that by his process both the objections just stated are removed, the alumina being produced in a condition of great purity, without a trace of iron, and so by care in the succeeding stages the aluminium itself is free from all contamination with foreign substances. In Webster's process the source of the alumina is potash alum. This is ground to powder and mixed with pitch and gas-tar, in the proportion of 8 parts of alum to 1 part of pitch and 1 part of tar. The mixture is then thrown on the bed of a reverberatory furnace and carefully heated. By this means the water only is driven off, while the sulphur and iron remain with a little carbonaceous matter in the cake. The operation requires careful attention, since, if the temperature be raised too high, burnt alum, which is unalterable, is the result. The fused mass is then removed from the furnace, and is ready for transference to the hydrate retorts. These are made of refractory fire-clay, and are vertical. They are charged from the top, whilst a mixture of steam and air is blown in at the bottom. At a red-heat decomposition takes place, sulphuric acid and sulphur, together with iron sulphate, being carried over mechanically by the steam and condensed in cisterns at the rear. The alumina and potash remain behind as a white cake, which is drawn from the retorts, transferred to a large tank, and lixiviated with water. The liquor which contains all the potash is run off into a pan and evaporated, while the alumina is transferred to bags and allowed to dry.

The Webster process appears to be a simple and successful one. All the by-products are regained, the potash and sulphur are extracted, the iron is thrown down as a fast and brilliant blue, and the residual sulphuric acid is concentrated for use. The alumina thus obtained is balled with charcoal and salt, made into a chloride and reduced for metal, the aluminium obtained being perfectly pure, and containing no iron whatever. The process is being worked by the Aluminium Crown Metal Company, and the metal itself combines strength and lightness with elegance of appearance and general utility. The metal is of two kinds, white and yellow, the former being used for cutlery and other table requisites where silver and plated goods are now employed, and for every kind of metallic fittings, lamps, harness, and carriage furniture, chains, wire, and wire ropes, and, in fact, for every purpose where a non-oxidizing bright surface is a desideratum, strength also being kept in view. The yellow metal is adapted and is stated to be used for guns, screw propellers, engine bearings, tubes, and all the various details of machinery where gun metal and other alloys are now used. The metal, as made, is supplied in ingots to the manufacturers of the various articles indicated, who produce the finished goods for the market. It is reported to stand exceedingly well in engine bearings, and also to give perfectly satisfactory results as applied to the manufacture of screw propellers. The metal is made in five qualities, and each quality is made either hard or soft as may be required. Samples of aluminium bronze tested by Mr. Kirkaldy have given very high results as regards tensile strength, one specimen showing an ultimate stress of 42.4 tons per square inch of original area.

Silveroid.

This metal was introduced to public notice in the early part of the present year. It is an alloy of copper and nickel adjusted with either zinc, tin, or lead in various proportions according to the purpose for which it is intended. Beyond this, however, there is a special method of treatment at a certain point in the manufacture which is stated to be the secret of success. The result is a metal of great whiteness, brilliancy, closeness of grain, and tensile strength. It is the invention of Messrs. Henry Wiggin & Co.,

and it is mainly intended to take the place of alloys of the brass, bronze, and gun metal classes, in fact of every inferior metal where color, polish, weight, and richness of luster are desirable. The author is informed that it is in use for machinery bearings and for all kinds of cocks, valves, and engine and boiler fittings.

Cobalt Bronze.

Since bringing out their silveroid, Messrs. Wiggin have developed another alloy, which is now being introduced under the name of cobalt bronze, and which is a whiter but slightly more expensive metal than silveroid. It is, perhaps, the more interesting of the two, because there is introduced into its composition small quantities of the metal cobalt. The malleability of cobalt in a pure metallic form has long been understood; but the author believes it was not until a few years ago that it was demonstrated by Messrs. Wiggin that it might be rolled into sheets, and wrought, like other metals, into articles of utility. Its high price, however, interfered with its production, and militated against its use. This fact induced Messrs. Wiggin to endeavor to compound an alloy in which the sterling qualities of this valuble metal could be fully represented, and which, at little more than the cost of ordinary German silver, might possess in a large degree all the attributes of the pure metal itself. Possessing, as it is said to do, many of the qualities and every appearance of metallic cobalt, it is manufactured in several qualities, the higher grades being preferable, on account of their suitability for casting purposes, their close steel-like surface, their susceptibility of a high polish, as well as their hardness, toughness, and great tensile strength. Cobalt bronze is intended to be used for the same purposes as silveroid, especially in high-class fitting work.

The author has now fulfilled the promise made at the outset of his paper, which was to place before the society a few facts concerning such modern bronze alloys as are being usefully employed for engineering purposes. He does not lay claim to any independent personal research or experiment upon the subject, such being precluded by the constant demands upon his time in other directions. He has consequently had to accept the results obtained by others, but he accepts them in perfect good faith. As they stand, they indicate the value and importance of the modern bronzes, and will serve as guides in the choice of a metal for a given purpose. The question of modern bronzes, however, is a very important one, and presents a wide field for scientific investigation and practical research. At the present time we are comparatively in the dark upon this subject, which has not received the careful attention at the hands of metallurgists that it deserves, and if the present paper only awakens attention to this fact it will not have been written in vain. It will be seen that the author has divided the bronzes into two classes, namely, those which come under the head of original productions and those which he can only consider as imitations. In thus distinguishing them, he desires to give offence to none, but he sees no way of evading what he believes to be a common-sense and equitable conclusion. In conclusion, the author will only suggest that, in selecting a material for practical use, proper regard should be had to the precise purpose the metal is required to serve, and that careful scientific preparation, based upon long experience, should be allowed to prevail against rule of thumb and a possible small saving in first cost. He would the more strongly impress this view of the case upon the members because he well knows that, although imitation is the sincerest form of flattery, flattery usually has to be paid for by someone or other.

For a considerable number of years proposals have been made for joining Sydney and the North Shore. Among the plans recently suggested for the connection of Sydney and the North Shore is that of a continuous suspension bridge, high enough to allow of the passage of shipping underneath. Mr. S. Pollitzer, C. E., of Sydney, has prepared a design of such a bridge, estimated to cost £430,000. The structure is designed to connect Dawes Point and the opposite headland. It includes two massive piers of masonry, which support the floor of the bridge at a certain height; and the cables are carried through the towers above. The central span is 700ft., and each of the two side spans 350ft. The height is given at 100ft. clear. The sectional area of the chains is 1104 square inches, and of the rods, 1152 square inches. The weight of wrought iron to be used is 7,880 tons, and that of cast iron, 945 tons; the weight of each abutment is 13,800 tons, and the mass of masonry altogether is 52,600 cubic yards. The cost per foot run is £307 3s.

THE MODERN ARCHITECT AND HIS ART.

By JOHN D. SEDDING.

From "The Building News."

In approaching the consideration of the modern architect and his art I feel, to use Mr. Lowell's recent words, that there is little chance of beguiling a new tune out of the one-stringed instrument on which we have been thrumming so long. Without, however, affecting to say anything new, "where everything has been said before, and said over again after," I desire to draw attention to a view of our art which has been singularly neglected, and which, to my mind, deserves infinitely more prominence than any words of mine can give it. What I have to say about modern architecture refers not so much to its archæological triumphs, its teeming types and annual revivals, nor to anything that therein is, but to that therein is *not*. So, also, what I would say about the modern architect refers not so much to his wide knowledge, bis daring anachronisms and matchless manipulations of historic ornament, but to his shortcomings—not to how he bewitches the general public by what he is, and what he could do if he tried; but to how the intelligent public may fairly be disappointed by what he is *not*, and what he cannot do. In a word, it is as as to the scope—or perhaps I should say the limitation—of modern architecture and the ideal of the design (if he have any) to which I wish to draw your attention. Naturally, I have chosen a subject which interests me, and, in pleasing myself, I hope I may please you; or at least I may offer an agreeable diversion to brains sorely racked and tired with studies and designs in various styles and periods. There is, I am aware, some danger attached to the criticism of a close profession like that of architecture, which has a royal charter dating from the 7th year of William IV., and which knows how to consume its own smoke. As, however, my point of view is quite an impersonal one, and my remarks general, and as I come before you without a single half-brick in my pocket to heave at anybody, my harmlessness is manifest. I shall then speak my humble mind with all the directness I can command, and trust to your kindness to take no offence where no offence is intended.

It is idle to shirk disagreeable questions, and so I begin with a simple proposition which covers much of the ground we shall traverse to-night. Is architecture, as practised by the modern architect, worth living for? It is a question I have more than once asked myself, but I am not candid enough to confess to you what reply I gave to it. In placing it thus in the forefront of this paper, let me say that the very last thing in my mind is to propagate doubt in the fold of the faithful where none exists; or to shake the confidence of such practitioners as are satisfied not only with the prospects of modern architecture, but with their own prospects and with the worth of their own contributions to the great volume of immortal art. To my mind the question is most suitable to the present time. I will not say that a "crisis" is approaching in the affairs of architecture, because the phrase has lost all its potency by frequent repetition in the newspapers, where we understand that a "crisis" occurs in national affairs every second day. But I will say that these are critical times for us. A strange calm has come. There is a sense of impending change. This is a time of felt uncertainty, of stranded purposes, of searchings of heart—a time when the issues of things connected with the arts of design are hanging in the balances. This is a time, too, of disillusionizing alike for architects and for people, when we ourselves are not quite so confident about our method of pushing architectural design forward by means of impulses of an essentially fleeting nature, and when people are beginning to realize that every branch of architecture is well represented by outsiders, and when they are beginning to question the *raison d'être* of the architect at all. This question is, then, a practical one, and one which it is desirable to face and to answer. It at once puts the

modern architect and his art in their right place. It makes us compare ourselves not with ourselves (which is not wise), but with the masters of old who brought trained powers, sleepless ambition, and passionate devotion to their work. It has this good effect, moreover—it at once breaks the spell of that direful boa-constrictor of art, mere professionalism. Yes, and in addressing it to the Architectural Association I cannot forget that I am speaking to those to whom the destinies of English design are to be committed, and it is for you to ask yourselves how you view and how you estimate the art you follow—whether you look upon architecture as a divinely inspired art that can rightly claim all the devotion of your being, or whether you take up architecture merely as an honorable profession and a gentlemanly calling. If you take up architecture as your vocation, to be followed with the ardor of a religion, I am not sure that you will succeed in gaining riches or fame; you may have to be happy with small opportunities and small gains, and have to live a life of quiet unnoticed worth. But you will be happy and contented and grateful all the same. If, on the other hand, you go in for architecture as a profession which only needs the efficient handling of a T-square and ruling pen, you may, if you are a good, steady fellow, rise to be an eminent practitioner. And if you are a successful practitioner your rewards are great; you may have access to the best society, and to the best columns of the *Times* newspaper; you may be a lion at evening crushes, and wear brown velveteen; you may pose as the patron of the very fine arts, and be a judge of *bric-à-brac*, and a connoisseur of Queen Anne teapots, Chippendale chairs, and such like; you may even hope to be the F. S. A. and the F. R. I. B. A., and even the P. R. I. B. A., if you have paid your subscriptions and are alive when your turn comes. Nay, if as architect and surveyor you have a sufficiently large and lucrative city practice and have time for such things, you may aspire to reach the souls of the people by the art of your tongue as well as by the art of your hand, and almost succeed in adding M.P. to your other titles. And to win these rewards you have only to be a rough-and-tumble ordinary man of the world, with a head on your shoulders, an eye for figures, a well-supported air of general competency, good business qualities, some power of gracious fooling, and the faculty of turning out just what the world expects from you with promptitude and dispatch. But as for art, and the mastery of the crafts, and the power of color and form and all that sort of thing, you may neither have any, nor need your friends suspect that such things come within the make-up of the modern British architect! Of course it is ever the snare of enthusiastic youth to press inconvenient speculations home, and it is because I am in the presence of the aspiring fledglings of artistic gifts and good parts who form the Architectural Association, that the question as to the innate worth of modern architecture comes before me. In another place, where the birds are not only fully fledged but have feathered their nests, and, like Jeshurun, are not exactly able to soar, I dare not hazard it, nor you either. Let it not be supposed that I have low opinions about architecture, or that I would willingly shake the allegiance of any young heart that has found peace in its pursuit. Let no waverer be downhearted; there may be a lucrative future before him. Let him stick to his last, by which I mean his T-square and ruling-pen.

To proceed. I said just now that this question touching the worth of modern architecture as a serious life's pursuit puts our art in its true place. Instinctively one feels that while it is applicable to the modern architect and his art, none but a fool would have put it to William of Sens, Jocelyn of Wells, Alan of Walsingham, William of Wykeham, Thomas Chard of Glastonbury, or of Bramante, Michael Angelo, Christopher Wren, Inigo Jones, or Adams or Chambers, and there must be a reason for this.

Again, none but a fool would ask the modern musician, or the sculptor, or the painter or poet if his art were worth living for. Indeed, here are living arts, each with its ideal conception to symbolize, each with its mission to stimulate, delight, and console mankind, and to raise men's minds out of money-grubbing grooves into a less selfish, less sordid, less commonplace atmosphere. It is significant that in each of these cases the artist is his own craftsman; he thinks

his own thought, clothes it himself, and spares no pains in the elaboration of the clothing. He keeps no ghost, and if he does he is not thought to be respectable. But the architect's ghosts are legion—on his premises and off them—and he is not one whit ashamed. In calculating the place and mission of the modern architect, one is reminded of what is happening in the bee-world just now. By the aid of an ingenious patent, ready-made cells are stamped out in wax (adulterated, of course) of the correct shape and size, and when placed in the patent hive the bees forthwith complete the cells and fill them with honey. And the very counterpart of this is happening in the human world; the royally-instituted architect makes the cells, and the decorators and manufacturers fill them with honey. You know quite well that the English people have not to thank the British architect for the poetry of their homes. You know that one of the noblest provinces of architecture, that of turning necessary articles of daily use into works of art, has fallen from the architect's hands. You know that all the pretty things that dignify modern life come from the "largest furnishing establishments in the world" in Tottenham Court road—from those homes of champagne and shoddy where the red sealing-wax "Early English" furniture, and the wood coal-boxes adorned with roses and daffodils and the cast-iron over-mantel china closets come from; where you may get a dozen very cheap high-class native oil-paintings at one counter, and a dozen very dear native oysters at another.

Again, we must confess that the other contemporary arts I have enumerated have been affected for the better and not for the worse by the influences of the day. Each has won new triumphs, each has found out new chances of appeal, new domains for display. But not so architecture, for while it has gained nothing it has lost nearly all. In respect of the use of iron for constructive purposes, and of patent sanitary appliances, which builders and sanitary engineers have devised for us, we score something. Yet, however blessed the iron joists and D-traps are, and however lucky we are to be able to use them, the architects of old, who knew them not, were infinitely more accomplished all-round men than ourselves; and I do not know that, after all, our houses are either more stable or more sweet and wholesome for body and soul to inhabit than the old homes of old England.

But further. The practice of these arts of color, sound, form and word directly conduce to the development of artistic genius; nor could you be a successful composer if you had no musical genius, nor an eminent literary man without literary genius. Yet you can be accounted an eminent architect, and reap all the honors of the profession, without possessing or feeling the want of artistic genius. In putting the case thus strongly, do not suppose that I am blind to the noble gifts and genius of certain architects working with us and shedding their helpful influence amongst us at the present time; and, but for my resolve to keep this paper impersonal, I would name them and speak of them with all the genuine admiration and respect I feel for them. Do not mistake me on this point; I speak of rank and file, and not of these. And I ask whether architecture as now practised ought not rather to be accounted as a "useful" than as an "ornamental"—or, as some would call it, a "fine"—art? I ask whether architecture can any longer be termed the "Queen of Arts," when all that remains of her is the skull and the feet and the palms of her hands? I ask if it be not true that architecture has ignominiously resigned her throne, lost her honors, and bartered the sceptre of pre-eminence with which she has held sway from time immemorial, and only reserved for herself the sovereign right of levying a tax of 5 per cent. on other men's labors? I ask whether it is not true that the engineer has (whether civilly or uncivilly it matters not, as the thing is done) robbed the architect of one-third of his domain on the one side, and whether the decorator and manufacturer have not between them robbed him of another one-third on the other side? I ask whether the architect of to-day is, or need be, anything more than a paper-draughtsman to sit on a stool and invent new sorts of doors and windows? I ask whether his business in life is not that of a designer of shells of houses for decorators and manufacturers to finish and furnish, and who varies this jackal occu-

pation by occasional jobs for an engineer, who hires him to do the "pretty" upon a bridge or railway station? Yes; and such of us who like to see iron skeletons clothed in shoddy ornament may, after refreshing our bodies, refresh our souls at the York or Bristol railway station, and realize at the same time the mission and scope of the modern architect and his art.

Now if you think that what I am saying is approximately true, you will agree with me that it is high time the position of the modern architect and the issues of his art were overhauled; and when this shall be undertaken, I know no better place for the investigation than under the roof of the house which contains the Royal charter granted expressly to a certain institute for the advancement of architecture and the various arts and sciences connected therewith. If it be for the better advancement of the arts and sciences that architects abstain from personal relations with them, then it must be granted that they are, with much self-denial and self abnegation, fulfilling the obligations of the charter under which they are enrolled. However this may be, I cannot help saying that, to my mind, every celebration of the Institute commemorates not the marriage, but the divorce of architecture from the arts and sciences connected therewith. I have laid before you evidences of this in what has already been said, and it would be easy to go on multiplying the proofs. Indeed, it is an undeniable fact that the arts and sciences which of old were ever indissolubly connected with architecture, have passed to the care and conduct of the specialist and the manufacturer. The British public goes to its shops and specialists for any matter connected with domestic art; and if you are a parson with wants, you go to an ecclesiastical shop, and while one shopman is fitting on your coat, or taking the shape of your parsonic head for a new stiff hat, you can be ordering of another shopman a sculptured reredos, an altar and font and lectern, and that sort of thing. Yes, and I saw a striking letter the other day, written by the head of a well-advertised carving establishment, which stated that, inasmuch as not more than half-a-dozen of the writer's architect clients could prepare their own detail in an artistic manner, he had started an office and staff of clerks to do for the architects what they could not do for themselves. And remember that the architects here referred to were of the Gothic school, which represents the best masters of detail. Even in the matter of building houses, the better sort of builder has his own staff of draughtsmen (or compiling copyists, as some would call them), who can invent new sorts of windows and doors, and draw convenient plans, and make pleasing combinations of colored materials after the approved fashion. The public may soon begin to inquire wherein the architects' clerks and the builders' clerks differ. The State, as you painfully know, has a very summary way of dealing with the architect, inasmuch as it entrusts its buildings to the engineers and officials of South Kensington, and maintains an office of salaried draughtsmen for carrying out public architectural works. And what is happening at Kensington, where engineers combine with ornamentalists to carry out the State's architectural works, may happen in other cases; for the public will see that, given a good builder, an engineer, and an ornamentalist, any building is possible. And the architect has only his own sloth and incapacity to thank for a state of things which in process of time will assuredly work his own extinction. The experts he has called into existence have silently undermined his position. He called in aliens to help him in his need, and the alien army is a standing menace to his position, and will in time dispossess him. Lacking science and lacking art, he is just nowhere if the scientist and the artist combine for his effacement. There is a good deal of what Mr. Ruskin would call professional "bow-wow-wow" talked at our conferences and in the journals about the rights and wrongs of the profession; but what cares the world about the architect so long as its wants are somehow supplied? Although we abuse it, the world is fair in this respect, it values us at its own valuation of our worth. It knows we keep ghosts, and it makes no nicely-drawn distinction between an "expert" and a duffer!

But in order to clear the way for some few practical observations I must arrange the subject under three heads: (1) What

is architecture, and what were the functions of the architect in old days? (2) When, and from what cause did the change from the old to the new system take place? (3) Is it possible for architecture under its present conditions to be carried out upon the old lines, and, if so, by what means? Here are three points, each of which would serve as a theme for a long lecture, so that my treatment of each must needs be brief and simply relative to the matter in hand.

As to the first point, although addressing a professional audience, I cannot define architecture as building erected after an architect's design. One might as well say that the snuffmaker was the final cause of the human nose! There is building which is, and building which is not, architecture; and I would define architecture as imaginative building; in other words, building which expresses the invention or imagination of the builder, and which appeals by this means to the imagination of the spectator. If it is to answer to the description of architecture, the building must have a soul as well as a body. The body is the structure answering to the primary purpose of its erection, and this body should be staple and convenient. The soul is that superimposed something extra to the body—that something which is provided beyond the demands of mere utility, and which is really the expression of the builder's thought and his mode of appeal to the sympathy and imagination of the spectator. In this definition you get the three cardinal virtues of architecture represented — namely, stability, which relates to science; convenience, which relates to good sense; and beauty, which relates to taste. Naturally, the primary purpose of a structure, combined with other like conditions, settles its character and the fit extent of its decoration; and yet, while it is quite fair to define the word architecture as the art of building nobly and ornamentally, you cannot gauge the value of a structure by the amount of its ornamentation. Dance, who built old Newgate, was an architect, and although his structure has dead black walls of rough-hewn granite, relieved only here and there with niches and statuary, and has a savage repellant air, it is imaginative building, and speaks directly to the imagination of the spectator of violence and doom in the true grim Northern manner. A mere builder would have put plain brick walls. And architecture all the world over has the same characteristic qualities—however different the types and the styles of the art represented, however different the scale of the structure, however different the culture and aims and methods of the builders—the architecture carries the impress of thought or invention, or imagination befitting an ornamental art. Architecture is truly a human art, a volume and record of human thought. As long as the structure remains you connect with it the memory of the men who built it. For instance, the monumental art of the west front of St. Albans Abbey is a more lasting memorial of its reputed father—our only British architect—than the cracked bell at Westminster. And so with other immortal specimens of other immortal artists, "soft-handed" or otherwise. As you look at the architecture of Egypt and Greece you associate it with its authors. The work is steeped in thought, instinct with invention, and—so far as its ornament is concerned—eloquent of pleasurable labor. It represents problems of proportions. Ideas are expressed with mathematical accuracy. In Greek art we have, as I need not remind you, the science of building united with accuracy of design and execution. The arts and sciences are here united perfectly. The tide of tradition is represented in full volume, and the designer is the exponent of traditions that commenced in Egypt, and flowed onward through the Greek and Roman and every other period till broken by the Gothic revival.

As I have just said, the architecture of the modern world answers, in all essentials, to the architecture of the ancient world, however different its aims, and character, and mode of appeal. With regard to the latter point, the Classic is a more intellectual art, and demands a more intellectual appreciation. The Greek architect is a man of complete culture, learned in philosophy and geometry, and he addresses his peers. This explains why it is some of us find the heights of Classic art cold, and the atmosphere that surrounds it bleak and grey. The modern architect, like the ancient, is the

right man in the right place; and, whether he be cultured or uncultured, prince or ploughman's brother, he is the most skilled man in the building crafts upon the job. The difference is that, being a Christian, he is no respecter of persons, and being a modern, he is no respecter of calculated academic rule, but speaks his thoughts simply and spontaneously, and addresses his art both to learned and unlearned, to rich and poor, to bond and free.

But now, as I turn aside to define the functions of the architect under the old system, I at once feel the ground shake beneath my feet. For who can forget the storm of 1874, after Mr. Fergusson's unfortunate deliverance in the *Quarterly Review* upon this very head? The story of that time affords, I think, a really valuable glimpse into the secret motives of the British architect. The veil lifts for a moment, and he stands revealed with the touchstone of his art in his hand. Directly the elevated position, the professional status and social level of the architect is threatened from below an army of "soft-handed gentlemen" rush to the rescue. Never in the annals of art (or the history of the Institute, which is the same thing) had so much power of eloquence, so much literary talent, and so much genuine enthusiasm been evinced. The British workman was supposed to be on the march to Conduit-street to demand enrolment as a Fellow of the Royal Institute, and to be, in this way, there and then constituted into an architect; and, although under the pressing exigencies of the case the parish beadle from the neighboring church, in all the majesty of his Sunday clothes, had been hired to watch the portals of No. 9, and although the Fellows had constituted themselves into a vigilance committee, in day and night relays, to guard their Magna Charta, something dreadful might have happened had the threatened invasion taken place. After all, however, the "unemancipated" British workman stirred not, but abode in his breeches, where I will return to him anon. Looking back at the pitiful affair (and the literature of the episode is innocently printed in the Institute's transactions "by order of the Council") I have only one remark to make, namely, that whereas the architects were preposterously alarmed lest the workmen should become architects, it never struck them to try themselves to become master-workmen, and so to gain the respect of the workshops by their own eminence in the crafts rather than by giving themselves airs because of their professional status and soft hands. Luckily for me, it is immaterial to our purpose to inquire as to the social status of the architect as a person, or whether he had soft hands or hard. One thing is certain about him —cultured or not cultured, hodsman's cousin or not—he contributed the requisite amount of knowledge and theoretical science, and did not retain experts; he was in direct contact with the work as it grew up; he saw how things were done, and was not the mere figurer of details at an office; he was the familiar spirit of the building, and not the distant dictator of its details. And besides having a general knowledge of handicrafts, he was master of at least one. Some architects were modelers, some carvers, some workers in marble, or in gold, or in ivory, and, plainly enough, we can infer that they worked in workshops, and not in offices or studios. "In Greece," Winckelmann says, "the best workman in the most humble craft might succeed in rendering his name immortal."

Let us turn for a few moments to Italian Mediæval art, for we know so much more about the architects of Italy than of those of any other country, and they afford us a ready type of men whose functions covered every matter pertaining to construction and ornament. The Italian architect was engineer, builder, painter, decorator, sculptor, modeler, metal-worker, goldsmith and the rest; or, at least you might expect that the same man could paint a picture, carve a subject, draw and model a bit of ornament, make a gold casket or an urn, design a dress or a fabric, build a church or a palace, or a bridge. Thus we see how wondrously the arts were interwoven and technical skill was diffused in Mediæval Italy. One craft overlapped the other; there was no hard and fast line of demarcation between them as with us, and no professionalism, and no Salvation Army of specialists behind the scenes. Naturally the poor Italian architect had never heard of the native Asian, African, and American styles so much in favor in

our classes of design; but had he professed to design any sort of building he would not have left it to the expert to fill it with plaster work, or marble, or wood inlays, or bas-reliefs and color devices; and his art would extend to the provision of gorgeous chests and furniture, and perhaps even to the dresses and portraits of his esteemed clients. Think of Da Vinci, with his superb power of color and form, of his magnificent designs and projects in art and mechanics, and set this man with his marvelous range, his almost superhuman grasp of mind and boundless ideal, against our puny selves poring over our D traps and ventilation, any quantity-taking, Metropolitan Building Acts, &c., &c.; and if, after instituting the comparison, you are satisfied with the scope and issues of the modern architect and his art, then I think you are eligible to be a Fellow of the Institute without further ado, and I will give myself the honor of proposing you on the first convenient occasion. Now, you cannot properly account for the high condition of Italian art in the middle ages by saying that the Italian people are a phenomenal people, with art in the blood. If so, art would be flourishing in Italy at this time, and it is not. The fact is, that whatever art you examine, of any period, or of any country, you will invariably find that the excellence of the work is only commensurate with the ideal. There is no luck, no chance about it, it is a simple matter of cause and effect; and if the members of the Institute had as high an idea of architecture, and of the various arts and sciences connected therewith, as they have of the privileges of the profession and of their professional status, English architecture would be different to what it is. It needs no prophet to foretell that so long as the modern architect contents himself with groveling views and consumes his soul in small things, so long will he grovel and do small things. In Italy, in the middle ages, there was a grand ideal to animate the artist and to sustain his art. Of course, many things conspired to favor art there and then, beyond the consanguinity with artistic races which doubtless had its effect. Italy was then what England is now—the world's emporium, the seat and center of the world's commerce. There was wealth, and the desire to spend it upon beautiful things. There was the ambition of cultured nobles; there was the inheritance of fine traditions; there was a lovely climate and a flowery land; there was the innate passion for beauty of a passionate and beautiful people. But what raised Italy to her high-water mark of art was the measureless value set upon execution. What Winckelmann said of Greece is equally applicable to Italy—the best workman in the most humble craft might succeed in rendering himself immortal. The designers themselves were masters in the crafts they dabbled in, and they had technical knowledge and technical skill. "Design" then meant something more than it at present does in an architect's office or in our classes of design. It meant the power to *do* as well as to *draw*. It meant executive power and technical skill. It meant that what the brain of the man could conceive that the hand of the man that conceived it could execute.

Coming to our second point we have to inquire when and from what cause the change from the old to the new system of architectural practice took place. And here we must come back to our own country again, first, because we are speaking of English art, and, secondly, because a similar change has not come over the architectural practice of other countries. I will begin by saying that the old system had lasted in the world generally from the building of the Tower of Babel to the time of the Gothic revival. Ever since English architecture was English architecture, it had been born and bred and fostered and propagated in English workshops. The Gothic revival meant not only confusion to architecture but death to the art of the workshop. I do not mean for a moment that the art of the workshop, or the craft carried on there, were of a high order before the inauguration of the new condition of things, but I speak of one system of design as opposed to the other system of design. How could the arts of design flourish then, when, from the king on his throne to the merchant on his stool, no one cared one dump for art? Why, the very life of art, its sinews, its flesh, and its bones is the living thought it contains, and the living interest it creates. If there were no de-

mand for literature, language would not be cultivated. If there were no dancers the piper would cease to play. Will the crafts develop their cunning if there is none to order and none to heed? It was not patronage only that was wanted, but employment. People, when they are uncomfortable about the results of the Gothic revival are fond of pointing to Gower street as a justification for the annihilation of traditional art. But you may depend upon it, had there been the demand for higher things there would have been the supply. However homely, or, if you like, however ignoble, the art done just before the new stimulus came, the traditions of the better times still lingered on in the workshops, and the bricklayer, the carpenter, and the plasterer who hung on were men with some notion of style and some love of detail. The early Queen Anne had its leanings towards the picturesque Elizabethan, and the houses of the period are singularly well adapted to English minds and English scenery, and their fittings are in nowise unworthy of the best traditions of the English workshop. I have purposely made this digression in order that I might insist upon the fact that so long as the traditional art remained in force, and the workshops were the nurseries of design, so long the old scope of architecture, and the connection of the architect with the crafts were maintained. And, while on this point, let me remark upon the significant fact that while certain architects still adhere to traditional art, English architecture gained no advantage by their adhesion; nor did they themselves strike oil, and for the simple reason that, like the Goths, they swamped the traditional art of the workshop with their new-fangled types and rolls of details prepared by the soft-handed clerks in their offices, and accomplished the complete strangulation of traditional art. So it comes to pass that the tale of honored names of English architects passes on from Pugin to Barry, Scott, Street, Butterfield, Shaw, Pearson, Bodley, and Philip Webb, and leaves them—shall I say?—inconspicuous in the crowd.

But I have yet to account for the decay of architecture before the Gothic revival, and also for the change from the old to the new system of architectural practice; and the explanation I offer for the one applies to the other. I have shown how low the arts had fallen at the beginning of this century through neglect, and I cannot see that you could expect that art should engage men's attention when you remember the vast number of social, political, and religious problems that were then agitating England. Professor Seeley's valuable book on the "Expansion of England" has helped me to see why the faculty for design died out with us in the 18th century, for he shows how entirely English interests were then centered in America and her other colonies. Think of the war ships that had to be built, the armies to be equipped, the colonies to be fought for and occupied; and, later on, think of the machine-looms and steam-engines to be invented and perfected, and the railways to be made! How naturally does the engineer spring into existence amid the demand for the useful arts! How naturally does the eye of the historian pass on to the record of that noble set of engineers and machinists and mathematicians — Davy, Watt, Cavendish, Arkwright, Herschell, Stephenson, and Brunell! And how natural that the men of genius should gravitate—not to the ornamental arts as in earlier days, but to the useful arts! Yes, one may well say that English science had produced a perfect vacuum long before the scientific investigator had discovered the way for himself, and that in an unsuspected direction.

And now, having considered the origin of the engineer, who is one of the cuckoo intruders in the architect's nest, let us turn to the origin of that still bigger bird—the ornamentalist or expert in the decorative arts. I said just now that the Gothic revival had inaugurated the change from the old system of architectural practice to the new. Before this revolution of taste took place, the architect was the leading spirit of the building he designed, but he did not stand alone. His designs or models for stone, brick, iron, wood, and plaster-work were backed by the traditional skill and types and methods of craftsmen, each of whom was more or less of an artist. The architect was only the prime minister; the workmen represented the departments. He was only the president, for the time being, of a little republic of art. From what we know of Wren, Inigo Jones, and the

Chambers and Adams, the architect was conversant with every branch of the work included in the structure. He supplied the plans and sketch elevations, and the leading details (as in John Thorpe's case), but the hundred and one odd details required for after-thoughts and emergencies might fall to the conduct of the workman, who, at all events, would be quite competent to deal with them if so required. Here, then, we have architecture carried out under the best auspices—where architect and workmen are in perfect sympathy in matters of taste, the designer has a fellow worker in the handicraftsman, one craft helps and overlaps the other, the executive and the theoretical go hand in hand like twin sisters, the structural and the ornamental proceed along the same lines, and we have building which deserves the name of architecture. The Gothic revival upsets all this harmony of procedure, for the whole of the traditions of the past must be sacrificed, and new types, mouldings, traceries, carvings, groinings, decorations, and the rest of it are introduced, about which the workman knows nothing and cares less. From henceforth you must look no more to the English workshops for the inception of types and evolution of ideas. The old *Têméraire* of English art having been sent to her last home, a bright new Venetian gondola takes her place, and rides proudly out to sea with seven Gothic lamps at her prow, an Oxford graduate and a few able enthusiasts to work the oars, fire off the guns, and take care of the cargo of sketch books and romantic literature on board. Naturally the gondola is first attracted to Venice, but as time goes on the taste of the crew changes, and you find them flying about in all directions, and bringing home valuable spoils in the shape of numberless new sets of doors and windows to offer at the feet of a grateful people. And the merit of the new types consists in this, that they are quite unique in England, and that the British workman cannot move a step, as he copies them, without full-sized details of every part. Now, my explanation of the origin of the specialist decorative artist is this. Having destroyed the old system of art, the Gothic revivalist found himself unable to construct a new system that would work; he had accepted a task which he was unable to cope with. He had a strong love of art, a true sense of the intimate relations of the lesser arts with architecture; but he found things too much for him, and, instead of raising an army of fellow-laborers in the workshops, he called into existence certain specialist assistants to aid him in the conduct of his practice, where he lacked time or ability to carry out the work himself. The mischief of the whole business has been that he was only a learner himself all the time he was carrying out works in various styles. He has been only a blind man leading the blind. He was up a tree all the time himself, and the specialist has been found an indispensable help in supplying his necessities.

I come now to my third point. Is it possible for architecture under its present conditions to be carried out upon the old lines, and if so, by what means? To the first division of this point my short answer is—No, and Yes. No, if the present conditions are to remain unchanged. Yes, if things change for the better. In dealing with the whole matter before us I do not want to arraign modern art for difficulties inherent to it, nor do I want to multiply the responsibilities of the architect. That some of the higher branches of an architect's work have been abandoned is undeniable; and I plead for the recovery of these at any cost. In claiming this I do not desire to extend the radius of the architect's proper work. I am even arguing for the lessening of his labors by bringing the handicraftsman into a more active participation in the work he has to do. This was the old system, and it is the only practical solution of the case. The question is, to what extent our present difficulties are inevitable or irremediable. I have no hesitation in putting at the head and front of our difficulties this of having to employ revived styles. Any suggestion that you or I can make which will indicate some way of mitigating our sufferings in this matter will therefore be a boon. We are in for the use of all the various phases of the various periods of architecture, extending from the 13th to the 18th centuries, in England and abroad; and when it is remembered that the giants of the past had all their work cut out to master the capabilities of one

style only, the vastness of our task is appalling. Every post brings us in a request from this quarter or from that for details of buildings which may each be of a different style. Add to this that one must keep touch with the progressive science of the day, and must be able to speak authoritatively of all the rival "sanitary specialities" and rival ventilating and warming schemes and electric lights, and hygeian rock and asbestos and American joinery, and the scores of dodges for minimizing art in the workshop, and girders and lifts, and "Acme" this, or "Imperial" that, and "Eclipse" or "Last for Ever" the other—to say nothing of having to pronounce off-hand upon Metropolitan Building Acts, and having to wade through surveyors' quantities and builders' accounts — is it any wonder that the architect gets so tired out with the business side of his work that he gladly leaves the problem of art production and ornament to the specialist decorator and manufacturer? You will observe, too, that at conferences and in presidential addresses and that sort of thing, where it is necessary to speak cheerily and respect the feelings of the profession at the same time the architect has invariably only one sovereign remedy to suggest—one patent salve is to heal all our disorders—and that is the specialist. The specialist, either inside or outside of the profession, is to ease everybody and everything all around! The proposal is that there shall be a sort of inner circle of the profession. The profession is to keep a paddock for the prize animals, who are to be warranted to have only one gift each, and who are to run around the paddock in a given groove all their lives. And all the sectionally-gifted persons are to make up one entire concrete architect, on the principle of making a quilt if you have enough patches to cover it. I grant you that, according to the present state of things, specialists must exist to do such things as these—to superintend the imitation of old work, to carry out decoration in a given style, Pompeian, Egyptian, Classic, or Gothic; to restore or build Gothic or Classic churches; Elizabethan, Jacobean, or Georgian houses, and the like. The question, however, arises here—are we to go on imitating the styles of the past? Specialists are necessary if we do go on in our present courses; but if we are to get out of the mists and on to the hill-tops again, we must train ourselves for our future liberty. If we want to perpetuate chaos and will-o'-the-wisp art, I do not know that we can devise a better means to that end than the establishment of representatives of the rival styles and the rival trickeries of the day. But surely we do not want practitioners of one accomplishment or one idea! Surely we do not want to ruin and degrade the noble art of architectural design by introducing into it that miserable division-of-labor system which (as Mr. Morris points out) has, in the case of our manufacturers, reduced the workman to a machine, effaced his individuality, taken away all the pleasure of labor, and destroyed the standard of excellence. The making of architectural design deserves a better system of procedure than the manufacture of a modern pin! Let us, then, listen—no, not for a moment—to the bewitching suggestions on this head. The disorder of modern architecture is too deep-rooted to be remedied by the quackery of a specialist. We will not allow the great factory and machine system introduced in the great art that has fallen to the care of our unworthy hands. Let us rather take courage and look forward to the time when the jumble of styles will be cleared away or reduced to system, and prepare ourselves for an all-round practice in our vernacular that is to be. Depend upon it that it will not be the one-eyed, or one-legged, or one-armed, or one idead specialist practitioner that will then be sought for, but it will be the architect with the most individuality, the most culture, the most skill, the most efficient training, that will be sought for, and found most useful to the architecture of the future.

But you may well now remind me of my promised suggestion of the means I would propose to bring about the redemption of the old ideals of our art. First, I would say, let architects determine at all costs to recover lost ground. Secondly, let architects endeavor to render the types now in vogue more malleable for nineteenth-century use in our workshops by classification or otherwise, by which means new traditions may be established, and the standard of excellence raised to something of its old

pitch. In regard to the first point, some of us have grown too old in naughty slothful ways to hope ever to accomplish much in the personal manipulation of the handicrafts, but we are none of us too old to determine, God willing, that our younger brethren shall have better chances than we had at their age, better chances for modeling and drawing ornament, and for taking their share in the design of house-fittings and the like. None of us, morever, are too old to help to dignify the labor of the workman whose dusty clothes soil the best Sunday-go-to-meeting coats of the members of the Royal Institute of British Architects, as they accidentally come in contact with him in the builder's yard. We are none of us too old to help to establish new traditions for the workshop, by classification of types and features done in such a way that they may appeal to the workmen in a more practical, familiar, and loveable way than they do now.

May I divert your interest for one moment from that all-important matter, the modern architect and his art, and ask you to look at the British workman. What is his condition? What are the issues of his life's work? What have you done for him? We left him in the eighteenth century, a magnate according to his personal qualifications in his little parliament of art, the workshop, evolving architectural types, and putting his whole soul into his work. In those days he was an intelligent being, following his craft joyfully because he excelled in it, and knew what he was about, and had a felt-place in the world. You have scattered those workmen, you have dissolved these little republics of art that in old days held sway in every town and village in the land, and what have you put in their place? You have drowned the English handicrafts by opening up the sluices of a ceaseless tide of archaic types, and how has your eclecticism affected the British workman? Certainly you have with a vengeance directed his eyes to the wonders of old art, and you have given the charm of novelty to his every-day occupation; you have introduced him to a very Pandemonium of tit-bit types; you have shown him how various have been the doors and windows in the buildings of past days; you have muddled his ideas and confused his brain, but you have done nothing to form his taste or settle his standards; you have added not one single pet moulding to his tool-chest, nor helped him to pigeon-hole a single familiar feature; he has no lasting impression of any piece of work you ever gave him to do. Had *he* had the origination of the changeful types that have passed before his eyes instead of *you*, he might have retained the same vague sense of things that you have yourself; but, as it is, his memory is no more fixed about the patterns he has worked than the loom which turns out patterns mechanically. He is in for the deluge, and no soft dove comes to whisper hope in his ear. He is the slave of caprice, the plaything of fickle humors, the sport of mutable tastes and veering winds of fashion. What a long dreary jest his life has been, and how, in his sober moments, he must sigh for the blessed, irredeemably bad art of the bad days before the deluge! Yet, in this much-abused, much-misunderstood, much-enduring, unheroic, untrustworthy, misbelieving, self-seeking, wife-beating, drunken, conceited, shallow, *Daily Telegraph*-reading, school-of-art trained man, behold the martyr of the nineteenth century. The Gothic revival proved the winding-sheet of his peace of mind, and one thinks that it had been better for his mental, his social, his moral and religious state, had the modern Gothic architect never been born! Nay, we of the Architectural Association would almost have preferred that he had been left daubing stucco-walls and chasing those curly ornaments and smiling cherubs on tombstones, and making those moulded Jacobean pews that we find so fascinating when we go to study Gothic architecture in some tip-top Mediæval church!

Just think of all the sad, bad, and mad architecture that has passed under the British workman's hand, say, in these last thirty-five years. In 1850 he was rearing a Norman apse upon the ruins of an old chancel that had been destroyed in the interests of morality and purism. In 1855 he was building a thirteenth-century hotel with details cribbed from Salisbury Cathedral, and a bank adjoining it in the Ducal Palace style. This took him some time. In 1870 we find him titivating an old Queen Anne

house in a Gothic manner; and in 1880 he was titivating a Gothic house in the Anglo-Foreign "Early English" Queen Anne manner; and now, in this year of the architect's salvation, he is satisfactorily completing the memorial of the nineteenth century at the west end of St. Albans Abbey, under the reputed direction of our all-accomplished, soft-handed, "emancipated," and only true British architect, Sir Edmund Denison Beckett, Q. C. Now, I want to know if we cannot do something to regenerate the art of the builder's yard and to raise the workman's position, and, if no higher motive affects you, think how it is for the interests of the modern architect and his art that you look steadily into this matter and do your best in it? I am firmly persuaded that there will be no good architectural design and no good execution until the craftsman can be brought to participate with the architect in the working out of architectural ornamentation. It is just one of those things about art which marks its divine origin and inherent dignity. You can get faultless mechanical work out of machines, and can get good mechanical work out of human machines; but noble hand-labor is only found where the workman uses his intelligence, and where he is able to express the individuality of the individual. I would say, then, begin the work of regeneration by throwing away all your petty professionalism. Give the workman his rightful participation in your aims. Let him see into your great mind. Make him something more than the transcriber of your hesitating lines. Lift him nearer to your own level of knowledge so that he may know something of the essential qualities of the style he is working in, and may at least interpret your thoughts sympathetically, render in his own idiom the things you put before him, and find some way of escape for the soul within him. Thus, and thus only, will you get good architecture and good sympathetic workmanship. Thus, and thus only, will you effectually and fairly lift some of the crushing load of responsibility and labor from your own shoulders, and get the helpmeets God made for you. The old architect lived long and saw good days because he was thus helped. But Pugin, Scott, Street, and Burges died young, and you know that the doctors say it is worry and not work that kills. This single-handed system of architectural design, where every detail must be supplied from the office, was too much for them. More than this. They were men of singular love of good workmanship, and nothing worried them more than to see their work carried out unsympathetically, or to find their designs carried out to a wrong scale, or their mouldings worked from the wrong side of the sectional line!

I conclude this paper with two propositions which aim at the amelioraton of some of the evils I have here enlarged upon. The first is as to the selection and classification of the architectural types now in vogue. The second relates to the provision of technical education for architects and craftsmen. With regard to the first point, it is clear that no scheme of architectural design has ever been practised without a basis of workshop traditions. Shall we then— is it worth worth while to try and formulate our tentative styles and to systematize our distracted types, with a view to rendering things permanent and to assist the workmen? If so, you must have a grammar and an alphabet before you can form words and sentences. Now it so happens that never since the world began has so much architectural knowledge been accumulated as is now stored up in the brains and on the shelves of the English architect. Why, then, should not these experts be set to work to formulate and render into serviceable shape the leading mouldings and forms and features of the styles in vogue? Why should not the destroyers of old English traditions do penance and make reparation for their naughty deeds, and build up new traditions? Why should we not have a well-arranged series of details of arches, capitals, bases, plinths, friezes, cornices, staircases, doors, windows, &c., for workshop use?

The second proposition is to have a technical college for the instruction of architectural design, to be for the use of architects and craftsmen. If modern architecture showed itself in as attractive form to the public as English music does, the scheme would receive the attention which we who know our pitiful state think that it deserves. One thinks that if the scheme were started under proper auspices it could not fail to receive the support of the Royal Academy, of the Insti-

tute of Architects, of the Architectural Association, and of all other public bodies who have any care for the advancement of the various arts and sciences connected with architecture. If such a college were set on foot, one might feel perfectly secure about the architecture of the future, for it might be expected to bring about that harmonious cultivation of the crafts without which the practice of architecture is a delusion and a snare. Depend upon it the hope of English architecture must come from the workshop, and not from the architect's office. Cast aside, then, as unworthy and profitless, the notion of specialists within or without the profession, and this for your own sake, your heart's sake, and the sake of the art of the future.

Cast aside also the notion that the mere personal taste, learning, theoretical knowledge, or power of penmanship of the architect will avail anything for the real advancement of art, unless the craftsman who works out his ideas reflects his accomplishments and can sympathize with his aims.

What we want is not so much men who can design in many styles of more or less remote antiquity, or men who can sketch well, but men of aim who can lead the aimless, men who by their personal acquaintance with the handicrafts and personal participation in the production of ornamental art can build up new traditions for the workshop, restore the credit of English workmanship, and recover the lost ideal of the English architect.

ON THE INFLUENCE OF SAND ON THE STRENGTH OF CEMENT-MORTARS.

By H. ARNOLD, of Wilhelmshaven.

Translated for Abstracts of the Institution of Civil Engineers.

After observing that not only the quality of the cement used, but that of the sand also, is a very important factor in the composition of mortar, the author remarks that in the case of sand, beyond general vague directions that it must be "clean and sharp," no detailed classification of the characteristics of different kinds, with directions how to obtain in all cases a normal or standard sand of uniform quality, was generally available for practical purposes until the publication of the valuable results of experiments carried out at Wilhelmshaven since 1877, in building the second entrance to the harbor. Taking first the ordinary local (Dangast) sand, a standard or normal sand was obtained from it by washing and sifting in the prescribed manner. This mixed with cement in the regulated proportion of 1 cement to 3 sand, gave a mortar whose tensile strength after seven days' setting was 5.93 kilograms per square centimetre (84 lbs. per square inch), and after twenty-eight days 6.60 kilograms, which does not nearly approach the standard of 10 kilograms prescribed in all contracts. An experiment similarly conducted with Berlin normal sand gave as follows:

After 7 days.....	10.56 kilograms
" 28 "	15.10 "

being an increase of 43 per cent. in the interval, and 78 and 129 per cent. respectively higher than when Dangast sand was used. Specimens of Dangast sand and cement sent to the Royal testing factory at Berlin gave the following results:

	After Seven Days.
Dangast sand.....	11.28 kilograms.
Berlin "	16.80 "
Difference.....	=49 per cent.

while experiments at Wilhelmshaven with Berlin sand and the very same cement gave

	After Seven Days. Kilograms	After Twenty-eight Days. Kilograms.
with Dangast sand	9.06	9.74
" Berlin "	14.24	18.44
Difference....	=57 per cent.	89 per cent.

The increase in strength from seven to twenty-eight days is therefore 32 per cent. for Berlin sand, and 7½ per cent. for Dangast sand, and from these and other

experiments it is abundantly proved that "the quality of the sand not only exerts considerable influence on the first setting of the mortar, but also materially influences the progressive hardening of it."

Further trials with the same cement, but with the various kinds of sand specified below, were made in order to test the influence of the sand itself.

1. Dangast ordinary building sand, weight, 1.61 kilogram per litre (100 lbs. per cubic foot); size of grain, very unequal and somewhat dusty; not very sharp.

2. Dangast sand No. 2. The same sand after further sifting; a somewhat smoother grain.

3. Dangast normal sand, prepared from No, 1 by washing and sifting. Weight, 1.506 kilogram per litre; grain, reddish and of uniform size; not very sharp. The microscope showed a rounding of the corners of the grains of quartz.

4. Wilhelmshaven common blue sand. Very sharp and extremely fine grain; contains hardly any soluble particles of mud and silt, and weighs 1.267 kilogram per litre.

5. Wangeroog sand. A somewhat coarser, but still a fine, very sharp clean sand, free from dust; weight 1.47 kilograms per litre.

6. Berlin normal sand. A sharp, clean, whitish quartz sand of uniform grain, and weighs 1.547 kilogram per litre.

Mortars made with these kinds of sands, and the same cement, in the regulated proportion of 1 of cement and 3 of sand, gave the following tensile strength:—

	After 7 days. Kilograms.	After 28 days. Kilogms.
Wilhelmshaven blue sand.....	7.15	9.40
Dangast normal "	8.78	11.10
" No. 2 "	8.98	11.04
" common building sand.	11.60	13.00
Wangeroog sand.....	13.58	16.74
Berlin normal sand.	17.60	21.94

These results show that the strength of mortars similarly made with the same cements, but different kinds of sand, depends on the coarseness and size of the grains of sand; and that in sands of equal size of grain that is the best whose grain is the coarsest. (Compare Berlin and Dangast normal sand in the above Table, where the difference in the strength of the mortar is about 100 per cent.) In order to determine the influence of the size of the grain, comparisons were made with seven specimens of Dangast sand of various sized grains, and also with granite chips, the result always being in favor of the granite chips. This also came out of the experiments, viz., that in sands of equal coarseness of grain that is the best whose grain is largest. (Compare also in the above Table, Berlin normal sand with Wangeroog sand, where the difference is about 30 per cent.) It was further established that coarseness of grain is a more important factor in the quality of a sand than the size of grain; and also that "a coarse sand free from dust gave better results than a fine sand of equal sharpness of grain." And further it was shown that sand containing uniformly sized grains is not always the best, since the ordinary Dangast building sand, which is somewhat dusty, invariably gave more satisfactory results than the sifted and washed Dangast normal sand of uniform size of grain. The author concludes by saying that, although different kinds of sand give materially different results in similarly prepared mixtures of mortar, it will not be justifiable in ordinary masonry to alter the prescribed proportion of cement and sand, viz., 1 to 3, unless the exact quality of the sand employed is known; and he recommends—

1. That the normal sand of the Imperial Testing Station at Berlin should be declared officially to be the only prescribed normal sand as regards not only size, but also sharpness of grain, and that thereby a standard for the strength of cement and sand mortars should be established.

2. That in all notices regarding cement, a comparison of results with this normal sand and with local building sands should be set forth.

3. That both the seven days' and the twenty-eight days' tests should be published, in order to obtain a scale of increase of strength in cement and sand mortars.

OBITUARY.

Samuel Henry Shreve.—Samuel Henry Shreve, the widely known civil engineer died in this city on Thursday, November 27th. He was known to the members of his profession throughout the country as the author of a treatise on "Bridges and Roofs," the greater portion of which was first contributed to this magazine. It was afterwards translated into French. Another work on the "Theory of the

Arch" was nearly complete at the time of his death.

It is difficult to say whether his greatest skill lay in expounding the principles of correct engineering or in directing their application in the field. In both fields of labor he gained high distinction. He was one of the engineers of the Rapid Transit Commission; was consulting engineer of the Metropolitan Elevated Railway, and chief engineer of the Brooklyn Elevated Railway.

Mr. Shreve was born in Trenton, August 9th, 1829, being the eldest son of Samuel Shreve, and his wife, Mary R. Stockton. Three of his grand-parents were of the latter name. The Shreeves were among the original Lord proprietors of New Jersey, and were distinguished in the Revolutionary War. He was graduated at Princeton in 1848, and was graduated in 1850 from the Harvard Law School and admitted to practice. His mathematical tastes, however, led him to adopt the profession of civil engineer. He was a member of the American Society of Civil Engineers and of the Century Club.

REPORTS OF ENGINEERING SOCIETIES.

ENGINEERS' CLUB OF PHILADELPHIA—RECORD OF REGULAR MEETING—November 15th, 1884.—Vice-President J. J. de Kinder in the chair.

Mr. John Haug presented a description, illustrated by drawings and test specimens, of Mr. William Astor's new Steam Yacht, the first sea-going steamship built of steel in this country. She is 235 ft. long on load waterline, 30 ft. beam, and 20 ft. deep, and has two complete decks of $\frac{1}{4}$ in. steel plates. Her machinery consists of a compound engine with cylinders 34 and 60 ins. diameter and 36 ins. stroke, supplied with steam of 85 lbs. pressure by 4 oval boilers built of steel, and having 170 sq. ft. grate surface and 4,200 sq. ft. heating surface. Her hull and machinery have been arranged according to Lloyd's rules for a class of 100 A 1, and she has been specially surveyed while building.

Mr. Fairman Rogers described the Steam Yacht "Magnolia," built in 1882, by the Herreshoff Manufacturing Company, Bristol, Rhode Island. The following conditions were required to be fulfilled in her design: Light draft, not more than 4 ft., length and breadth such as to enable her to pass through the Erie Canal locks, which are 100×18 ft., flat floor, large accommodations for cruising and for a long residence of the owner's family on board, flush deck, no projection of steam drums, etc., above deck, except the smoke-stack. Low speed, not less than 8 miles per hour. Minimum head room below, 6 ft. 6 ins. Adapted specially for inland cruising along the Atlantic coast. She turned out to be entirely satisfactory. Her ordinary speed is 10 miles, maximum 11½ miles.

The Secretary presented, for Mr. E. F. Smith, an illustrated description of a Floating Coffer-Dam, which is used in removing obstructions from the channels of the Schuylkill Navigation Co. Its dimensions are 32 ft. by 48 ft., and 20 ft. by 36 ft., formed by the union of two halves, which, when placed end to end, could pass through the locks of the canal. This form also enables its easy removal from around a pier after construction. It has water-tight boxes to float it, and to hold the stone to sink it. When in use it is surrounded by sheet piling, and the latter surrounded by puddled clay. It has been worked in from 7½ to 11 ft. of water. It cost $1,128.32 in 1879, has been much used, and is still in good order; 7 men can shift it, complete, in four to six working days. Average cost of four shifts, $86.19, for labor. 5 to 10 per cent. of new sheet piling is required for each shift. A 6-in. Andrews centrifugal pump, run three minutes out of every ten, keeps it clear of water. Rock obstructions are removed by steam drill, and blasting by battery.

Mr. Theodore Bergner, introduced by the Secretary, exhibited his designs for Drawing Boards.

Mr. Robert P. Snowden presented an illustrated mathematical discussion of Formulæ for Frogs and Switches, with some notes as to putting in leads for the same.

The Secretary presented, for Mr. Graham Spencer, a description of the Kaolin Beds of Chester Co., Pa., and Newcastle Co. Del.—describing the methods of mining and refining the clay.

Mr. Allen J. Fuller exhibited a new form of Transit Rod, which is made so that the point of the shoe is in the same plane as the face of the rod There is an opening through the rod, from about 9 ins. above the point of the shoe to a height of 6 or 7 ft. At the top of this opening and on the face of the rod, is suspended a plumb-line, which hangs across a marked cross-piece near the lower end of the opening. The plumb-line indicates when the rod is plumb, after which it may be fastened to a hook on the underside of the cross-piece to prevent oscillation by the wind. The transitman sights to this line, which, with the dividing line on the face of the rod, forms a right line throughout its length, perpendicular to the point over which it is set. The rod is provided with short stay-chains, attached to pins, for driving in the ground, that will hold it when set over a tack center or stone monument. It is also designed to be used instead of plumb-bobs in taking horizontal measurements with the tape-line, to save time and insure greater accuracy.

The Secretary presented, for Mr. R. H. Soule, illustrated notes upon the West Shore Anthracite Engine, No. 24, 8-wheeled, of which class there are 30 on that road. This engine was designed by the late Howard Fry, Member of the Club, Supt. M. P. of that road. It is massive and utilitarian in appearance, all ornamental mouldings and brass work having been studiously avoided. The domes and stack are after English practice, and the cab is unusually large. In performance they have excelled the bituminous engines, which is principally due to the fact that the firebox of the anthracite engine rests on the top of the frames, raising the ash-pan higher above the track than is the case with bituminous engines, the fire-boxes of which drop down between the frames.

Mr. W. Bugbee Smith described, with illustration, the method of removal of the West Philadelphia Stand Pipe, which was taken down in 1881, and the masonry and ornamental cast-iron work used in the construction of the Spring Garden Stand Pipe. The new pipe, which is of the same general design as the old, is 5 ft. in diam, and 156 ft. 6 ins. high, being 20 ft. higher than the old. The lower 53 ft. were of $\frac{3}{8}$-in. iron; the middle 50 ft., of $\frac{5}{16}$-in. iron, and the upper 53 ft., of $\frac{1}{4}$-in. iron. The longitudinal seams for the first 53 ft. were double riveted; all other seams single riveted. The bottom sheet was double riveted to a cast-iron flange. The weight of the pipe and flange was about 16 tons. The pipe was erected in one piece, by means of two poles, one on each side of the pipe, and was then lowered about 6 ft., and bolted to the top of the base casting. This operation took about 1 h. 40 m. The base casting is 5 ft. diam., 5 ft. 3 ins. high, and receives the 36-in. inlet pipe on one side. It is secured to the foundation masonry by four $2\frac{1}{2}$-in. bolts, which are keyed on the under side of large plates below the masonry. When the pipe had been secured, the ornamental masonry was built about it, to the height of 37 ft. To erect the ornamental iron work, which consists of columns in 10-ft. sections and a spiral stairway, a carriage supporting two sheaves was placed upon the top of the pipe, where it turned freely. A rope ran up one side of the pipe, over the sheaves and down the other side, by means of which the columns, etc., were hoisted into position. The work was done upon a movable platform which surrounded the pipe, and rested on the rings which joined the tops of the columns. As each section of columns was secured in position, the platform was hoisted ready for the next section.

St. Louis Engineers' Club.—The club is now in excellent working condition, and there seems no reason why it should not so continue. The success of the past year is due to a generally awakened interest in the matter, which can be largely traced to the work of the Committee on Programme, who provided for so valuable a series of papers for the meetings. It is perhaps not too much to say that no local Engineers' organization in this country has done better work in the past year.

The Committee on Programme for the next six months reported through their Chairman, Prof. C. M. Woodward. The report was accepted and the Committee discharged, the duty of executing the scheme devolving upon the incoming Executive Committee. The report is as follows:

St. Louis, December 3, 1884.

Mr. President:

Your Committee on Programme for the coming season beg leave to submit the following report:

Your Committee are aware that they have an important duty to perform. The arrangement of a programme includes the fixing of the dates on which the Club shall regularly meet during the next six months; the acceptance and often the assignment of subjects; and above all the securing of the active co-operation of those members of the Club able to present valuable papers.

They are happy to state that they have found no lack of excellent material, and that, as will be seen below, several papers will be held in reserve.

The programme we submit is as follows:

December 17, "Earlier Floods in the Mississippi," by J. A. Ockerson, U S. Assistant Engineer; January 7, "Economy in Gas Engines," by J. Sobolewski, Inspector St. Louis Gas Co., and "Protection Against Fire and Means of Extinguishing the Same," by C. T. Aubin, Engr. to Board of Underwriters; January 21, "The Use of Compressed Air," by C. Shaler Smith, Engr. Ills & St. Louis Bridge Co.; and "An Improved Crane," by Frederick Shickle, of Shickle, Harrison & Co.; February 4, "Eliminations of Errors in Field Work," by Wm. Bouton, City Surveyor, and "Mill Creek Sewer," by Wm. Wise, Chief Assistant Engr. Sewer Dept.; February 18, "Street Pavements," by Thomas H. Macklind, Chief Assistant Engr. Street Dept., and "Improvement in Switches," by Hubert Taussig, Engr. in charge of St. Louis Depot Yards; March 4, "Experiments in Hydraulics," by Henry Flad, Pres. Board of Public Works," and "Treatment of Wood for Street Pavements," by T. D. Miller, City Gas Inspector, and T. J. Caldwell, Special Expert on Wood Preserving; March 18. "Pile Driving and Related Work," by C. V. Mersereau, U. S. Assistant Engineer," and "The Use of Diagrams of Crank Effort in Designing," by W. H. Alderdice, Assistant Engineer U. S. Navy; April 1, "Amsler Integrators," by M. L. Holman, Chief Assistant Engr. Water Dept., and "Construction in Wood and Iron," by K. Tully, Architect and U. S. Assistant Engineer; April 15, "Steamboat Shafts," by H. W. Baker, U. S. Assistant Engineer, and "The Efficiency of a Pair of Holtz Machines, one Acting as Generator, the other as Motor," by F. E. Nipher, Prof. of Physics, Washington University; April 29, "The Utilization of Fuel by the Generative System," by Wm. B. Potter, Professor of Mining and Metallurgy, and "Dynamometers," by Chas. F. White, Supt. of Shops, Manual Training School; May 13, by Frank H. Pond, of Pond Engineering Co., and "The Theory of Car Starters," by J. B. Johnson, Prof. Civil Engineer, Washington University; May 27, "The Theory of Ammonia Refrigerating Processes," by C. M. Woodward, Dean of Polytechnic School, Washington University, and "Report of the Committee on Smoke Prevention."

Several papers have been half promised and are held in reserve for cases of unavoidable failure, and for additional meetings should the Club see fit to continue semi-monthly meetings into the summer. Your Committee recommend that this Programme, when adopted be printed as a circular and distributed among the members of the Club, and other interested persons.

ENGINEERING NOTES.

Cost of Carriage by Rail and Canal.—A canal from the Westphalian coal district

to Emden being projected, the author compares the cost of carriage upon canals and on a single line mineral railway with a few stations and a small staff. Assuming eight trains of sixty loaded wagons per day to the port, of which twelve are returned loaded, and a cost of £6,000 per kilometer for building the line, as actually incurred for similar lines in the district, he calculates the cost per train-kilometer as follows:—

	d.
Repairs and renewals of locomotives...	1.20
Fuel.....	2.40
Cleaning, oil, &c.....	0.54
Repairs and renewals of wagons.....	2.88
Lighting and heating of guard's van....	0.22
Drivers' wages, including mileage.....	1.41
Guards' and brakesmen's wages, including mileage	2.46
Inspection, &c., of rolling stock.....	0.13
Station-service.....	3.12
Permanent-way, repairs, and signalmen.	4.32
General management.....	1.56
Interest on capital account for line, locomotives, and wagons, at 4 per cent...	14.52
Total.....	34.56*d*

or $\frac{34.56}{3.60}$ =0.096*d.* per ton-kilometer = 0.16*d.* per ton-mile.

The carriage on the Elbe canals costs 0.35*d.* per ton-mile, and on the canal from the Belgian coalfields to Paris 0.29*d.* in spring and 0.34*d.* in autumn 1883, without paying interest. Estimating the cost of the Ems canal at £16,000 per mile, and adding 4 per cent. of this, the carriage on the canal would cost about 0.4*d.* per ton-mile. The items in the above estimate are calculated from the actual returns of similar German lines.—*Abstracts of Inst. of Civil Engineers.*

Protecting River Banks from Caving.—A novel system of protecting river banks against the consuming action of an everflowing current is being applied near Memphis, Tennessee, along the Mississippi, where a caving bank rises straight up from the water's edge from 10 to 50 feet. There is an incessant lapping and chafing by which the bank is slowly worn away and undermined, and, as a consequence, it breaks down piece by piece, and is dissolved and carried away by the river. To check this steady but slow disintegration is the problem which United States engineers are trying to solve satisfactorily. The idea of a blanket placed along the slope of the bank from high-water mark to the bed of the river naturally suggested itself, and the contrivance adopted, a willow and pole mattress, represents the blanket theory. The woven webs are some 50 feet wide and from 200 to 1,000 feet in length, with flexible willows worked in for woof and poles and wire for warp. These are made on boats having a length equal to the width of the mattress, and as the mattresses are completed they slide away into the water. The sunken mattresses, it is said, prevent undermining below the low-water line, and the grading down of the over-hanging bank stops the undermining above that line. The space between the upper edge of the mattresses and the top of the bank is protected with willows and stone. All this mattress-grading and stone-covering is embraced in the term revetment. The work already done by the American engineers and the staff of workmen is described as being of the most substantial character. The appropriation of $200,000 secured from the last Congress for this work will, it is estimated, be sufficient to place mattresses along the river front from Wolf River to the foot of Beal or Linden Streets. The work will probably be completed before the next rise of the river. It remains to be seen whether it will hold the bank and prevent it from further caving. Next spring, when the floods turn the Mississippi into an inland sea, the practical test will be made, and if the mattresses hold the banks successfully against the impinging and undermining current, the mattress revetment theory will be sustained.

IRON AND STEEL NOTES.

In an article in *Dingler's Journal* "On Utilization of Slag," Mr. A. Frank recommends the application of magnesium chloride for the decomposition of slags containing sulphur and phosphorus. The fluid slag is run into a solution of about 1.06 sp. gr. and agitated; the sulphides are decomposed with the evolution of hydrogen sulphide; so in basic slags uncombined lime produces calcium chloride and magnesia, which indirectly induces a concentration and more easy solubility of phosphates present. The magnesia thus produced can be removed by washing and settling. On heating in an oxidizing flame the slag powder obtained with the still adhering magnesium chloride, or with a further addition of chloride, a partial higher oxidation of the ferrous oxide and similar compounds results, the new compounds formed being less prejudicial to the manure obtained. Instead of beginning with fluid slag, solid slag finely ground can be heated with the magnesium chloride solution under high pressure. In place of magnesium and ammonium chlorides, the sulphates can be used along with free hydrochloric acid.

By a modification of Rocour's process for working up phosphorized slags, described in *Ding. Polyt. Journ.*, the slag is melted in a cupola, whereby a matt is obtained containing 20 to 25 per cent. of phosphorus. It is then mixed with powdered anhydrous SO_4Na_2, and heated to redness. Most of the phosphorus is changed into sodium phosphate, whereas a portion of Fe and Mn is converted into phosphates, sulphides and oxides. The mass is treated with water to recover sodium phosphate by crystallization. The insoluble residue is mixed with Na_2SO_4 and charcoal, and heated in a reducing flame. The Na_2SO_4 is first converted into Na_2S, and then by double decomposition sodium phosphate and FeS and MnS are formed. The mass thus yields another crop of sodium phosphate crystals. The residue, after roasting to destroy the sulphides, can be used as an iron ore rich in Mn. The sodium phosphate is employed for artificial manure. Another method to work the phosphorized matt is to fuse it in a Bessemer converter with dolomite or lime. Alkali can be added to promote the fusing of the

metal slag which is formed. Before the complete dephosphorization the slag is decanted, and a fresh portion of lime added to obtain the dephosphorization according to the basic process. The slag contains P_2O_5 and only little Fe and Mn. It is powdered, and used either directly as manure or after treating with SO_4H_2 as superphosphate. The second method yields the P as a product of less marketable value; but as the metal has been converted into steel, its value is said to make up the difference.—*Engineer.*

RAILWAY NOTES.

RAILWAY PROGRESS IN NEW SOUTH WALES.—In 1883 the total earnings of the New South Wales railways were £1,931,464; total working expenses, £1,177,188; and the net earnings £753,676. The total cost of construction amounted to £14,382,102; the cost of rolling stock, workshops, machinery, furniture, &c., was £2,520,912; and the total capital expended £16,905,014. But for heavy reductions of charges, the receipts would have been increased by £100,000.

STEAM ON LONDON TRAMWAYS.—A satisfactory trial has taken place of one of the fifteen steam tramway locomotives now being constructed by Messrs. Merryweather & Sons, of Greenwich, for the North London tramways. These engines have cylinders 7½ inches diameter by 12 inches stroke, and are each capable of drawing three loaded cars at a speed of eight miles per hour, and at a stated working cost of 30 per cent. less than horse-power. It is expected that the whole of these engines will be running in the course of the next two months.

THE extension of the Brighton electric railway line having now been in active operation for six months, a few particulars may be interesting, as showing the capabilities of a light line of this description; the details of construction have been already described in our columns, and need not, therefore, be repeated. The car mileage amounted to 15,600 miles, or 100 miles per diem, the number of passengers in round numbers, 200,000; this figure would be increased but for the fact that at certain times the would-be passengers exceeded the capabilities of the car, which seats thirty persons only. No accident has occurred to either the general public or to passengers by the car. The consumption of gas in the gas engine has been 300,000 cubic feet, or 13 cubic feet per passenger per mile. The total cost of traction, including interest and depreciation on engine, dynamo, and motor, cost of gas, oil, and attendance, has amounted during that period to 15s. 6d. per day—100 miles run—say 2d. per mile. The car service has only been stopped for one day through the tires of the wheels giving out, owing to the heavy pressure of the holiday traffic, there being at the time no second car available.

ORDNANCE AND NAVAL.

IMPROVEMENTS IN TORPEDO APPLIANCES.—A noteworthy improvement in torpedo appliances on board torpedo craft has just been perfected at Portsmouth after a course of practical experiments under way in the harbor at Spithead. Hitherto the attack of outrigger charges has been delivered from the front by means of a spar, 35 feet in length, which was run out over the stem of the boat, and exploded from the conning tower after the charge had been submerged to the requisite depth. From a tactical point of view this method had the obvious disadvantage of arresting the way of the craft at the critical moment, and of seriously retarding her retreat after having accomplished her purpose. The cause, however, which has brought about the improvement was less tactical than mechanical. It was found that when the pole was lowered for action it almost invariably snapped off short by reason of the resistance of the water when running at high rates of speed. Wood was superseded by steel tubular booms, but without any advantage, the metal, besides being more cumbrous and expensive, proving just as brittle and uncertain under the like conditions. In these circumstances recourse was had to a device which was suggested by Captain Noel some ten years ago, but which was at the time reported against as impracticable. This was to deliver the attack from the side by means of a swinging pole, which would give way gradually under the pressure of the water. One of the new poles has now been fitted (according to the *Times*) to No. 13 first-class torpedo-boat at Portsmouth, under the superintendence of Mr. Gowings, by whom all the initial difficulties suggested by the officers of the *Vernon* have been satisfactorily overcome, and the gear will become a service fitting for all torpedo craft as well as the swift boats which are now in course of construction by Mr. J. S. White, of East Cowes. The new pole is made of wood, and is fixed by a swivel aft. Its length is 45 feet, or 10 feet longer than those hitherto in use. It has an arc of safety ranging from 30° before to 30° abaft the beam; and by reason of an ingenious contrivance, though the officer in charge might, in the hurry and confusion of the moment, move the firing-key before the charge had traveled to a safe distance from the boat, it will not explode until the indicator shows that the limit of danger has been passed. It was also necessary to provide against the chance of the head of the pole being forced under the boat carrying it through coming against the protective nets and booms of the enemy, and the torpedo being fired while in that position. This danger has been met by preventing contact being made after the charge has been sunk below 20 feet. It has likewise been thought expedient to adopt precautions against the risk of premature explosion by the production of "an earth current," by the overflow of the sea.

ARTILLERY EXPERIMENTS AT SHOEBURYNESS.—Some interesting artillery experiments were made on May 27, at Shoeburyness. The principal feature of the day was the trial of a new compound armor plate constructed by Messrs. Cammell & Co. It was 10 feet 8 inches wide by 9 feet high, and 19 inches thick,

6⅝ inches being steel and the remainder wrought iron. It was arranged that the 80-ton gun, with a charge of 450 lbs. prism powder and a Palliser shell of 1,700 lbs., should be fired at the plate at a distance of 120 yards, and that should this shot, as was anticipated by some, not succeed in breaking it, four other shots from an 11-inch breech-loading gun of 43 tons should be fired at the four corners of the plate. The plate was fixed by sixteen bolts to a backing of 11½ inches of teak, constructed on a frame identical to that designed for Her Majesty's ship *Camperdown's* target at the water-line, the only difference between the *Camperdown* and the target erected being that the teak backing in the former is 19 inches thick, whereas in this it was only 11½ inches. The plate also in this case was 19 inches instead of 16 inches. The gun having been loaded, the company present retired under shelter and the shot was fired, striking the target, as was calculated, with a velocity of 1,594 f. s., and with a total energy of upwards of 30,000 foot tons. The result of the experiment was that the projectile penetrated about 8 inches into the plate and was broken to atoms. The armor plate was radially split into five different pieces, one of which was entirely detached. Behind the backing nine of the sixteen bolts were found to have been broken, and the iron frames representing the ship's side were bent and torn. To account for this result it was claimed, no doubt with some truth (says the correspondent of the *Times*), that the framing of the target to which the plate had been attached was too weak in its structure, and from want of support it had buckled considerably from the impact of the shot. The fractures showed that the welding of the steel face to the iron back was perfect throughout, and was an excellent specimen of manufacture so far as soundness was concerned. After the satisfactory results which had on former occasions been obtained in firing against a compound armor plate with a granite backing, the experiment on May 27 was no doubt disheartening. Consequent, of course, upon the shattered condition of the plate, it was not possible to carry out the remaining portion of the experiments with it, and the rest of the day was taken up with some interesting practice with the various guns which had been mounted. Shots were fired from a Hotchkiss quick-firing gun constructed for sea forts, but owing to the manufacture of the cartridges not being very satisfactory the practice was only moderately good. Experiments with the Hotchkiss quick-firing gun for naval service, mounted on a pedestal, were made, and it was found that the gun was capable of being fired with aim once in every 4½ seconds. One hundred of these guns have been ordered for the service, as well as one hundred of Nordenfelt's quick-firing 6-pounders; they are intended to be used as an auxiliary armament to ships. A 12-pounder breech-loading gun was next shown, mounted on a hydraulic Woolwich field carriage, which has been constructed in competition with one made by Messrs. Armstrong. The trail of the Woolwich carriage is lighter than Messrs. Armstrong's; the recoil averages on ordinary ground nearly 6 feet. Three of these carriages have been constructed for experiments at Okehampton, and eighteen of Messrs. Armstrong's similar carriages have been ordered and will be served out for practice. Messrs. Armstrong's 18-pounder breech-loader, which has been made to take the place of the old 16-pounder, was shown. It was mounted on an Armstrong steel field carriage, with a brake, which, however, was found not to work very satisfactorily. After luncheon a 5-inch breech-loading sea-service gun was shown, also a 6-inch breech-loader and an 8-inch breech-loader, the former being mounted on an Armstrong carriage with friction compressor, and the latter on an Armstrong converted carriage with a hydraulic buffer. The practice of these three guns was at 2,000 yards, at 6 feet by 6 feet targets. The skill with which they were laid was highly creditable, and the action of the fuses was satisfactory.

BOOK NOTICES.

PUBLICATIONS RECEIVED.

SELECTED Papers of the Engineering Society of the University of Michigan; First and Second Series.

An Ephemeris of Materia Medica, Pharmacy and Therapeutics. By E. R. Squibb, M. D.

Abstracts of Papers in Foreign Transactions and Periodicals. Edited by James Forrest, Secretary of the Institution of Civil Engineers.

The Journal of Microscopy and Natural Science.

Transactions of American Institute of Mining Engineers, Vol. 12.

Report of the Board of State Engineers of the State of Louisiana for 1882-83-84

Sound Signals. By Arnold B. Johnson. New York: D. Appleton & Co.

The Magazine of Art for 1885.

Cassell's Family Magazine. New York: Cassell & Co.

Professional Papers of the Signal Service. No. XIV., Charts of Relative Storm Frequency of a portion of the Northern Hemisphere.

PROPOSED PLAN FOR A SEWERAGE SYSTEM AND FOR THE DISPOSAL OF THE SEWAGE OF THE CITY OF PROVIDENCE. By SAMUEL M. GRAY, City Engineer. Providence: Providence Press Company.

This report is an exceedingly well printed and well-illustrated book of 146 pages of text, and many good maps. As most of the volume is a carefully prepared treatise on Sewerage Systems and treatment of Sewage in general, it will prove to be a valuable reference book for the practical engineer.

MANUAL OF GEOLOGY—THEORETICAL AND PRACTICAL. By JOHN PHILLIPS, LL. D., F. R. S. Edited by Robert Etheridge and Harry Govier Seeley, F. R. S. London: Chas. Griffin & Co. Price $6.50.

This work appears in two parts. Part I. is devoted to Physical Geology and Palaeontology, prepared by H. G. Seeley, F. R. S.

By far the greater portion of this volume relates to Physical Geology, and includes one of the most satisfactory treatises on Lithology in the English language.

The illustrated examples are mostly those of British Geology, and, with the exception of a few new ones prepared for this edition, they can hardly be regarded as embellishments.

So much is presented in this treatise that is not in other accessible books that students of Geology cannot well afford to be without it.

APPLIED MECHANICS. An Elementary General Introduction to the Theory of Structures and Machines. By JAMES H. COTTERILL, F. R. S. London: Macmillan & Co.

This may be regarded as a complete elementary treatise on practical mechanics.

The several sections treat, respectively: Statics of Structures, Kinematics of Machines, Dynamics of Machines, Stiffness and Strength of Materials, and Transmission and Conversion of Energy by Fluids. These five sections are divided into twenty-one chapters.

Examples for practice are given at the end of each chapter. The illustrations are numerous, and tolerably good.

Students who desire a work presenting all the subjects of Applied Mechanics in a form easily mastered by moderate mathematical attainments will find their wants well supplied by this book.

THE SEAMAN'S GUIDE TO THE LAW OF STORMS. By W. H ROSSER. London: Norie & Wilson. Price $1.00.

A compact little essay on the Law of Storms is here presented in twenty-eight pages of text, which are made also to include the few necessary wood cuts. It may be regarded as a text book for seamen. A collection of examination questions is furnished at the end of the volume.

Although not designed for general reading, this book is well calculated to satisfy the want of the general inquirer who seeks to become familiar with the practical side of the growing science of Meteorology.

ELECTRICITY IN THEORY AND PRACTICE. By LIEUT. BRADLEY A. FISKE, U. S. N. New York: D. Van Nostrand. London: F. & N. Spon. Price $2.50.

This book is written with the object of forming a connecting link between the many works written on the theory of electricity and those written on its practical applications. The author states in his preface that practical men find great difficulty in mastering this subject, because they have to study the theory of electricity from books devoted wholly to theory and the practical applications from those devoted wholly to practice, and he endeavors in the present work to remove this difficulty by considering the theory of electricity in connection with its practical applications. The book opens, after an elaborate table of contents, with a chapter on magnetism, in which only the leading facts and phenomena are touched upon, and then the author proceeds to the consideration of frictional electricity. There is nothing novel in the treatment of this part of the subject; we notice the customary engravings of the various machines, better executed than is ordinarily the case, and a very well written description of the Holtz machine. The idea of potential, which is usually so incomprehensible to students, is very lucidly explained, and the chapter on voltaic batteries is extremely full and complete. The discussion of Ohm's law in the following chapter leads us to the consideration of quantitative measurements, and this is followed by an explanation of the practical units in which currents are measured, and examples illustrating their use and showing how the current varies according to the grouping of the cells.

Electro-magnetism is very clearly dealt with in chapter eight, and the convention of magnetic lines of force is rendered very easy of comprehension by excellent diagrams. An account of electrical measurements is preceded by a description of the sine and tangent galvanometers, and we must point out that in his discussion of the principle of the sine galvanometer, Mr. Fiske has made use of ambiguous terms, which would probably leave a wrong impression on the mind ot the student. He refers to the couple tending to pull back a deflected magnetic needle into the meridian as being measured by the product of the earth's magnetic force, the strength of one pole and the distance between them, whereas he should have been careful to point out that it is the horizontal component only of the earth's magnetic force that enters into the couple. It is a defect in the chapter on magnetism that there is so little information in it on the subject of the earth's magnetism. Several forms of ampere meters and voltmeters are excellently described in this chapter, and the manner in which the engravings are executed is beyond all praise. The account of telegraphy in the following chapter gives a description of all the systems of working commonly in use, and is a most interesting and instructive article.

The chapter on the electric light possesses no particularly novel feature, and we are somewhat disappointed in not finding some practical information on the subject of installations and methods of working.

Electric machines receive a fuller treatment than is to be found in most text books; there is a splendid folded engraving of the Weston machine, and also smaller ones of the Brush and Siemens machines. This chapter also contains a discussion of the characteristic curves of dynamos, which is a valuable addition. These curves, first suggested by Dr. Hopkinson, offer a graphic representation of the relations of the strength of current to the electromotive force, and therefore to the magnetization of the magnets. Under the heading of electric distribution of power, the author discusses the problem of the transmission of power in the form of electric currents, and gives a series of tables taken from the *Electrical Review*, London, showing the amount of horse-power lost per thousand yards, in conductors of different sizes, with currents of different strengths. There is also a full account of the various sytems of electric distribution, by which power may be distributed with a comparison of their relative advantages and disadvantages This

chapter may be considered as the principal feature of the book, for in it the author departs from the ordinary routine of the text book, and applies the theory which has been studied in the previous chapters to the consideration of problems of a more practical nature.

The book concludes with an account of electric railways, in which the two systems for propelling cars by electricity, viz., firstly, by a storage battery carried by the car, and, secondly, by a conductor which transmits the electrical energy to the motor, are dealt with. The difficulties that arose in the solution of the problem of applying electricity to locomotion, and the way in which they were surmounted, are fully explained and the student is thus made conversant with all that is at present known on the subject. As a scientific text book this work is sure to find considerable favor amongst students and teachers; the reasoning is at all times clear and explicit, and the general arrangement of the book leaves little to be desired. To the student who is desirous of becoming an electrical engineer, it will be a most valuable assistance, as it goes beyond the point at which most books leave off, and shows how theory is applied in practice. We have already had occasion to note the excellent engravings with which the book is illustrated, and we will only add further that it is got up in a manner which we regret to say is seldom seen in this country. —*Engineering.*

ATTACK AND DEFENCE OF COAST FORTIFICATIONS. By CAPTAIN EDWARD MAGUIRE, Corps of Engineers, U. S. A. D. Van Nostrand. Price $2.50.

As Captain Maguire shows, the changes of the last generation have not lessened the importance of fortifications as the main defence of coasts and harbors, however much they may have enlarged the role and increased the importance of auxiliary defences, such as submarine mines and movable torpedoes. More powerful guns will be required to keep hostile vessels off at longer range, and heavier works will be required to accomplish the same result. Stone must give place to iron in casemated batteries, and earthern parapets at least forty feet in thickness should be provided for open unarmored batteries which are still useful in localities sufficiently high above the sea level, say the level of the maintop of war vessels, and in no case less than twenty-five feet, in order not to be commanded by the turrets of armored ships. Depressed carriages must be used in such batteries to secure protection for the gunners while loading, and mortar fire must be developed to the utmost, to assail armored vessels at their weakest point by a vertical fire. Magazines must be sunk quite below the *terre-plein* to protect them against the penetrating power of projectiles. Machine or rapid-firing guns in abundance must be added to the armament of all open batteries to worry the gunners, as well as the man at the wheel, and the commander in the conning tower, while heavier guns are piercing or racking off the armor. Channel obstruction, fixed and floating, becomes increasingly important, owing to the great speed of war ships, which would, without it, carry them speedily out of the range of slow-firing, heavy coast guns. These several necessities of the modern defence are clearly set forth by Captain Maguire. Submarine mines can never, he argues, replace guns. The mine has but one life, while the activity of the gun is limited only by the supply of ammunition, and the mine must be operated by the expert, while the guns can be fought by the multitude and without very great training. Captain Maguire's book does not profess to be anything more than a compilation, but it is a very useful compilation, bringing together a mass of facts which have outgrown the received text-books, and are only to be found scattered in the current periodical literature, and presented in a variety of languages. The German, Austrian and French text books treat the subject of modern coast defences in a very general way, and the information they give is limited. The English text book devotes thirteen pages to a brief review of the subject, and that from a purely English point of view. Professor Mahan, in his Permanent Fortifications, gives but little attention to coast defences, and his work is in any case out of date. The latest text book that covers this subject in any measure is the new edition of Professor Wheeler's text book on Military Engineering. In this the subject of coast defences is treated generally in a chapter of nineteen pages. None of the works to which we have alluded consider naval operations against coast defences and the fighting strength of fleets, subjects which are of the first importance in determining the character, location and armament of coast works. Hence this work of Captain Maguire will be found to be an excellent supplementary and companion volume to the received text books on the subject of the art of fortification, such as that of Professor Wheeler, which is, of course, much wider in its scope. Professor Wheeler's purpose is to give a clear statement of the general principles and rules observed by engineers in the construction of modern fortifications, thus guiding the student to the intelligent study of the development of the art of fortification, and the history of the various systems employed in the past. As it is a book for class-room instruction details are omitted, so far as may be, explanation and instruction being left to the instructor. At the same time Professor Wheeler's work is one which may be read or studied with profit by those who, without making arms their profession, are desirous of keeping themselves informed as to the principles and progress of the military art, which, in its relations to the defence of States, becomes of interest to every citizen. It is not to be expected that either Professor Wheeler's work or that of Captain Maguire will reach the circulation of dime novels, but the more widely they are read and studied the firmer foundation we shall have for an appeal to popular judgment on the subject of providing against the possibilities of national humiliation through foreign aggression. Our national lack of reverence displays itself, among other ways, in indifference to, or ignorant contempt for, the opinions of those whose life-long study of a subject of national moment entitles them to be listened to with respect

when they call attention to our public danger and its remedy. As an intelligent and enlightened member of the Democratic party, Mr. Dorsheimer well said, during the last session of Congress, from his place in the House, "You may say the conditions of Europe are impossible to America. But these very streets we look upon have heard the cannon of Bladensburg. They have beheld the bayonets of General Ross. History repeats itself. It is bound to do so again. It may come upon us as a thunderclap. And, for one, I do not desire to be identified, within or without partisan boundaries, with any party that squarely sets its face against the defence of our country from the probable insult or the possible invasion of a foreign enemy."—*Army and Navy Journal.*

MISCELLANEOUS.

Righting a Chimney.—There are various ways of righting a tall chimney which has inclined out of the perpendicular. The method pursued recently in the case of the chimney of Messrs. Pattee & Perkins' machine shop at Holyoke, Massachusetts, displays several novel features. The chimney in question is 80 feet high, 8 feet square at the base, and 6 feet at the top. Three "harnesses" were put on the base, the first one being-placed under the cornice, and the other two below the first. The chimney leaned to the north of west, and was 42 inches out of the perpendicular. Two lever jackscrews were placed under the girders of one of the harnesses on the west side and six jackscrews under the harnesses on the north side. The earth was then removed on the south and east sides to below the foundation of the chimney. Then the earth was carefully combed and loosened with iron rods under the south-east corner. Water was next forced into the loosened earth by means of hose. Finally the jackscrews were turned up slowly and carefully, and the chimney was forced to an upright position after repetitions of the loosening, puddling, and turning of the screw. When the work of righting was finished, the earth on all sides was puddled, and the chimney is now said to stand pointing towards the zenith.

According to an article "On the Decomposition of Cements by Water," by H. Le Chatelier, in the *Chemisches Centralblatt*, he has studied the progressive decomposition of cements by water. Hydrated cements when treated with excess of water give up lime; it has hitherto been supposed that the dissolved lime was free lime, and it was determined in this manner, hence the varying results obtained in different laboratories. These amounts are proportional to the water used, the calcium salts ceasing to be decomposed when the water contains a certain percentage of lime. The free lime may, however, be determined by solution by using very little water at a time, and only removing it on becoming saturated—1.3 grms. CaO per liter. In this manner no calcium compounds will be decomposed, calcium ferrite, the least stable compound of all, only beginning to decompose when the solution contains about 0.62 grms. CaO per liter. It was found in this manner that the slowly hardening cements always contain a large amount of free lime, whereas the quick setting are almost free from it. By the progressive action of water each of the constituents is decomposed in turn, giving a particular amount of lime per liter in the water, which amounts remain constant for each lime compound decomposed. The question cannot be completely answered, as in the solution of the lime there are certain stopping places, corresponding to which there have been as yet no lime compounds prepared synthetically. The author is therefore inclined to the opinion that silico-aluminates and silico-ferrites are formed in hardening, although he has not as yet succeeded in preparing them artificially.

New Form of Primary Base Apparatus: by T. W. Wright.—In Wright's *Treatise on the Adjustment of Observations* (D. Van Nostrand, New York) there is a description of a new form of primary base apparatus. The measuring bar is of metal packed in melting ice. The length of the bar will remain unchanged throughout the measurement, as its temperature is constant, being that of melting ice. The same temperature can at any time be had at which to find the length of the bar in terms of the official standard of length. The apparatus might be constructed as follows: The measuring bar, a bar of steel 25^{mm} in diameter and 6^{m} in length, placed in a circular cast-steel tube $\frac{1}{8}^{m}$ in diameter, made stiff by bracing, but as light as possible. Along the top of this tube slots of about 75^{mm} in width would be cut to allow the introduction of ice around the bar. The hole for drainage would be at the center of the tube on the under side. For supports during the measurement two trestles placed $1\frac{1}{2}^{m}$ from the ends would be best. Effects of flexure would be got rid of by having the graduation marks showing the length of the bar placed on the neutral axis of the bar. The reading microscopes, alignment apparatus, sector and level for determining the inclination of the bar during measurement, such as those made by Repsold for the U. S. Engineers. The mode of measurement the same as with the Repsold apparatus. The amount of computation necessary to reduce the measurements made in this way would be small in comparison with that required with the forms of apparatus at present in use. The scheme is entirely practicable in the United States, at least where ice is to be had everywhere at all seasons.—*American Journal of Science.*

Correction.—On page 362 of our last volume (Nov. No.), in 9th and 10th lines of the second column, there is a fraction whose denominator is printed 3^{0}. It should have been 3^{3}.